Note: S.G.O. Medical Intelligence Branch informed us that their copy of this report had page stubs between pages 106 and 107, and between pages 122 & 123, just as ours does. Our report is O.K.
5 Nov. 1948.

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Indexed

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Title:
THE UNITED STATES
STRATEGIC BOMBING SURVEY

Dept. Army Misc.

Regraded unclassified by Dept. Army circular #21 May 1, 1950

THE EFFECTS OF THE ATOMIC BOMB ON HIROSHIMA, JAPAN

Volume III

Physical Damage Division

May 1947

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THE UNITED STATES

STRATEGIC BOMBING SURVEY

THE EFFECTS OF THE ATOMIC BOMB ON HIROSHIMA, JAPAN

Volume III

Physical Damage Division

Dates of Survey:

14 October – 26 November 1945

Date of Publication
May 1947

~~SECRET~~

This report was written primarily for the use of the United States Strategic Bombing Survey in the preparation of further reports of a more comprehensive nature. Any conclusions or opinions expressed in this report must be considered as limited to the specific material covered and as subject to further interpretation in the light of further studies conducted by the Survey.

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FOREWORD

The United States Strategic Bombing Survey was established by the Secretary of War on 3 November 1944, pursuant to a directive from the late President Roosevelt. Its mission was to conduct an impartial and expert study of the effects of our aerial attack on Germany, to be used in connection with air attacks on Japan and to establish a basis for evaluating the importance and potentialities of air power as an instrument of military strategy for planning the future development of the United States armed forces, and for determining future economic policies with respect to the national defense. A summary report and some 200 supporting reports containing the findings of the Survey in Germany have been published.

On 15 August 1945, President Truman requested that the Survey conduct a similar study of the effects of all types of air attack in the war against Japan, submitting reports in duplicate to the Secretary of War and to the Secretary of the Navy. The officers of the Survey during its Japanese phase were:

Franklin D'Olier, *Chairman.*
Paul H. Nitze, Henry C. Alexander, *Vice Chairmen.*
Harry L. Bowman,
J. Kenneth Galbraith,
Rensis Likert,
Frank A. McNamee, Jr.,
Fred Searls, Jr.,
Monroe E. Spaght,
Dr. Lewis R. Thompson,
Theodore P. Wright, *Directors.*
Walter Wilds, *Secretary.*

The Survey's complement provided for 300 civilians, 350 officers, and 500 enlisted men. The military segment of the organization was drawn from the Army to the extent of 60 percent, and from the Navy to the extent of 40 percent. Both the Army and the Navy gave the Survey all possible assistance in furnishing men, supplies, transport, and information. The Survey operated from headquarters established in Tokyo early in September 1945, with subheadquarters in Nagoya, Osaka, Hiroshima, and Nagasaki, and with mobile teams operating in other parts of Japan, the islands of the Pacific, and the Asiatic mainland.

It was possible to reconstruct much of wartime Japanese military planning and execution, engagement by engagement, and campaign by campaign, and to secure reasonably accurate statistics on Japan's economy and war production, plant by plant, and industry by industry. In addition, studies were conducted on Japan's over-all strategic plans and the background of her entry into the war, the internal discussions and negotiations leading to her acceptance of unconditional surrender, the course of health and morale among the civilian population, the effectiveness of the Japanese civilian-defense organization, and the effects of the atomic bombs. Separate reports will be issued covering each phase of the study.

The Survey interrogated more than 700 Japanese military, government, and industrial officials. It also recovered and translated many documents which not only have been useful to the Survey, but also will furnish data valuable for other studies. Arrangements have been made to turn over the Survey's files to the Central Intelligence Group, through which they will be available for further examination and distribution.

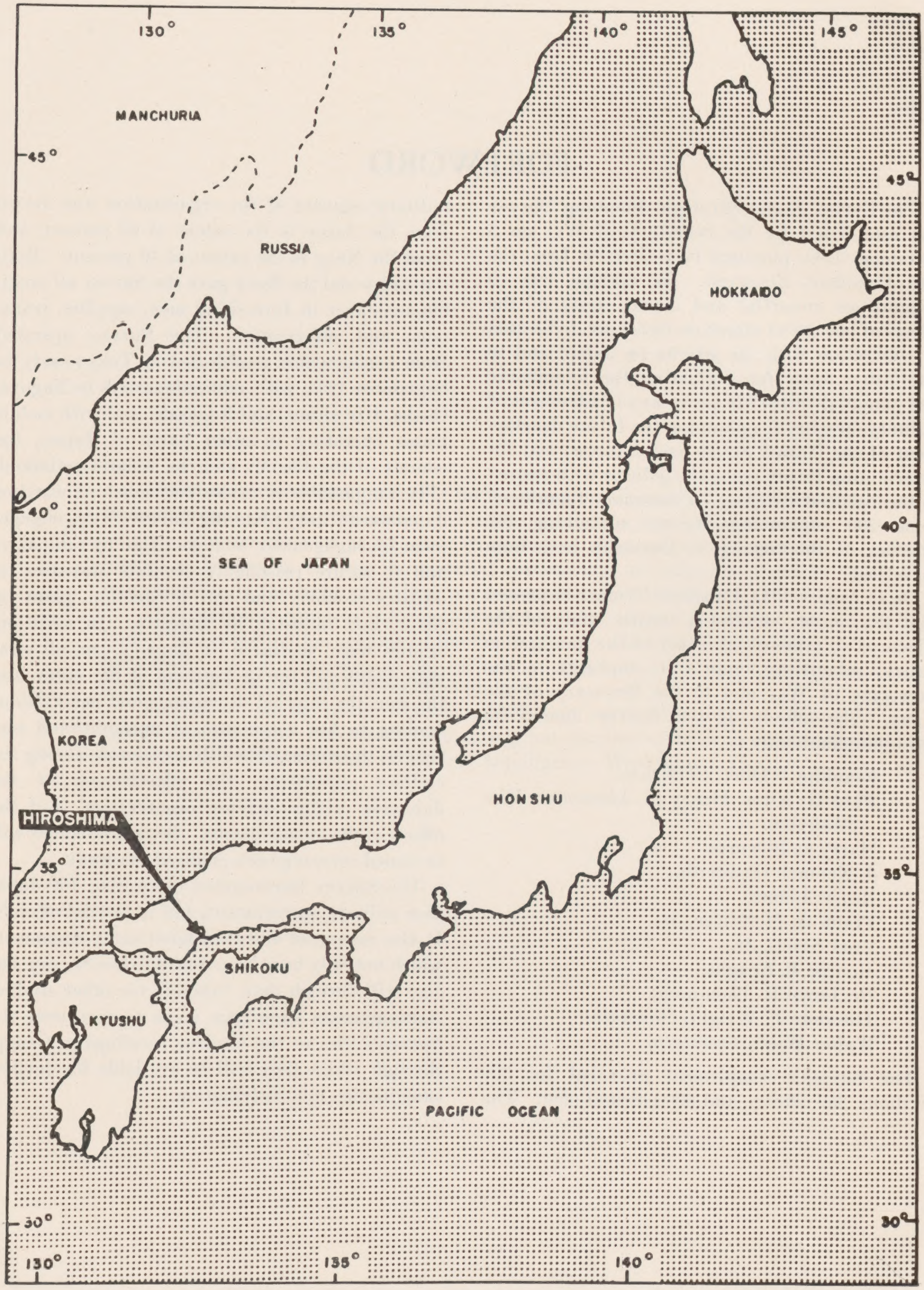

130°
135°
140°
145°
MANCHURIA
45°
RUSSIA
HOKKAIDO
40°
SEA OF JAPAN
KOREA
HONSHU
HIROSHIMA
35°
SHIKOKU
KYUSHU
PACIFIC OCEAN
30°

TABLE OF CONTENTS

REFERENCE TABLES

TYPES OF DAMAGE

Damage to Buildings, Industrial and Domestic

a. Structural.—Damage to principal load-carrying members (trusses, beams, columns, load-bearing walls, floor slabs in multistory buildings) requiring replacement or external support during repairs. Light members such as purlins and rafters are not included.

b. Superficial.—Damage to purlins and other light members stripping of roofing and non-load-bearing exterior walls. Damage to glass and interior partitions not included.

Damage to Machinery, Utilities and Equipment

a. Total.—Not worth repair.

b. Heavy.—Requiring repair beyond capacity of normal maintenance staff; usually returned to manufacturer.

c. Slight.—requiring repair within capacity of normal maintenance staff.

Damage to Contents Other than Machinery and Equipment

a. Total.—Not usable.

b. Other.—Usable if reprocessed or repaired.

TABLE A.—*Building types or classifications*

[Tables A and B from Joint Target Group]

Group		Type symbol	Description
A. Single-story, no traveling cranes, spans generally less than 75 feet, heights at eaves generally less than 25 feet, area of 10,000 square feet or more.	1. With saw-tooth roofs	A1.1	All buildings of this group with saw-tooth roofs other than those included in types A1.2, A1.3, and A1.4.
		A1.2	Frame and roof slab of monolithic reinforced concrete.
		A1.3	Exposed top chords of trusses.
		A1.4	Stressed-skin type of reinforced concrete (e. g., Zeiss Dywidag).
	2. Without saw-tooth roofs.	A2.1	Simple beam and column.
		A2.2	Arches and rigid frames.
		A2.3	Truss construction.
		A2.4	Frame and roof slab of monolithic reinforced concrete.
		A2.5	Stressed-skin type including concrete shell.
B. Single-story with traveling cranes; any length of span; area of 10,000 square feet or more.	1. Buildings housing heavy cranes.	B1	Buildings containing runways for heavy cranes (capacity 25 tons or more); height at eaves generally more than 30 feet.
	2. Buildings housing light cranes.	B2	All buildings in this group other than those in B1.
C. Single-story; no traveling crane runways; spans greater than 75 feet; height at eaves generally greater than 25 feet; area of 10,000 square feet or more.	1. Main frame members in two directions.	C1.1	Roof trusses supported along one side of building by long span trusses and along other side by columns. Permits large door along one side and at ends.
		C1.2	Continuous trusses in one or two directions; long span in one direction, supported by columns or exterior walls and by internal columns.
		C1.3	Exposed chord saw-tooth roof buildings; exposed chord trusses supporting major size trusses at 90°. One or both truss systems may be of long span.
		C1.4	Diamond mesh arch.
	2. Main frame members in one direction only.	C2.1	Long-span arches, individually supported along sides of building. May be arranged in multiple spans joined along side.
		C2.2	Long-span, triangular or bowstring trusses, individually supported by columns at sides of building. May be arranged in multiple spans joined along side, using common columns. Roof pitch exceeds 2 in 10.
		C2.3	Long-span trusses, top cord of pitch 2 in 10 or less, including exposed cord saw-tooth roofs, individually supported by columns along sides of building. May be arranged in multiple spans using common columns or may be continuous over internal columns.
	3. Shell-type construction.	C3	Stressed-skin including concrete shell construction.

TACLE A.—*Building types or classifications*—Continued

[Tables A and B from Joint Target Group]

Group		Type symbol	Description
D. All single-story buildings of less than 10,000 square feet plan area.		D	This type covers all single-story industrial buildings, regardless of type of construction if under 10,000 square feet in plan area.
E. Multistory frame buildings		E1	Earthquake-resistant; extremely heavy steel reinforced-concrete, multistory construction, designed to resist heavy lateral loads.
		E2	Structures in this group other than those in E1.
F. Multistory, wall-bearing buildings (may have internal columns).		F1	Earthquake-resistant, wall-bearing construction (walls of brick reinforced concrete, or very massive masonry).
		F2	Structures in this group other than those in F1.
S. Special structures		S	Coke ovens, test cells, fuel storage, boilers in power plants, etc.

TABLE B.—*HE vulnerability classes*

HE vulnerability class	Substructural groups (Symbols refer to Table A)	HE vulnerability class	Substructural groups (Symbols refer to Table A)
V1	E1.	V4	A1.1, A1.2, A1.3, A2.1, A2.2, A2.3, A2.4, D.
V2	B1, B2.	V4A	C1.2, C1.3, C1.4, C2.3.
V3	E2, F1.	V5	A1.4, A2,5, C1.1, C2.1, C2.2, C3.
V3A	F2.		

FIRE CLASSIFICATION—BUILDINGS AND CONTENTS

C—*Combustible:* Buildings whose roofs and/or walls are constructed of combustible material. The floors (except the ground floor) are required to be of similar construction. Wood-frame buildings with noncombustible sheeting on roof and/or walls are also included in "combustible" class.

N—*Noncombustible:* Buildings which have no significant amount of combustible material in the structure, but whose structure is susceptible to damage by fire in the contents. An example of this type is a building with exposed steel members which may be warped irreparably by the heat of a fire. Roofs of this type are corrugated asbestos corrugated iron, pre-cast or pour-in-place cement or gypsum on exposed steel and reinforced concrete 2½-inches thick or less.

R—*Fire-resistive:* Buildings which have no significant amount of combustible material in the structure and which will withstand all but the most intense fire without structural damage. Roofs and floors (other than ground) should be of concrete more than 2½-inches thick, and the steel frame should be protected and not subject to ordinary fire damage.

C and N, N and R or C and R used where above types are combined in a single fire division.

SECTION XI
DAMAGE TO MACHINE TOOLS

1. Object of Study

The object of this machine tool study was to determine the extent of, and to analyze the factors involved in, the damage to machine tools by blast, debris, fire, and exposure to weather resulting from the explosion of the atomic bomb in Hiroshima on 6 August 1945.

2. Summary

a. General. The major industrial plants of Hiroshima were located about 1½ miles from the heart of the city and no damage was done to machine tools in them. Numerous small engineering shops, principally light ones containing two to forty machine tools, were located within the area seriously affected by blast and fire. Although the number was small, all machine tools within 3,500 feet of ground zero (GZ) were seriously damaged, principally by fire. Except in four unburned shops, all machine tools throughout the 4.4-square-mile, burned-over area were seriously damaged by fire after sustaining not more than 15 percent serious damage by debris. Serious damage to machine tools in excess of 15 percent was caused by debris in only one unburned shop, which was within the burned-over area. Debris and weather caused only slight damage to machine tools outside the burned-over area.

b. Scope of Report. Machine tools in 19 one-story buildings (11 wood-frame, 5 steel-frame, and 3 load-bearing, brick-wall structures), all of which were combustible except one, were included in this study. There were no multistory or reinforced-concrete machine shop buildings. Four of the 19 buildings were outside the burned-over area and were unburned, but were within 7,600 feet of GZ. Fifteen of the buildings sustained structural damage, mainly 100 percent. The high-explosives vulnerability of all buildings was V4 (reference tables).

c. Wood-Frame Buildings. Debris caused total or heavy damage to only 3 percent of the machine tools in wood-frame buildings although 64 percent of the total floor area was structurally damaged by blast. Wood-frame buildings which were collapsed by blast apparently fell as units with appreciable lateral motion, and as a result comparatively few machine tools were seriously damaged by debris. Serious damage by debris resulted mainly from overhead shafting and pulleys crashing down. A few machines were slightly damaged when overturned by mass movement of the building frames. Fire was the principal cause of serious damage to machine tools in wood-frame buildings. Seven of the 11 buildings were burned and all their machine tools were seriously damaged. Serious damage by fire resulted because of the combustibility of the buildings and their contents, and the congested areas in which they were located.

d. Steel-Frame Buildings. Debris caused no serious damage to machine tools in steel-frame buildings although 42 percent of the total floor area was structurally damaged by blast because the blast caused mass distortion of the steel frames without tearing loose heavy structural members; moreover, wall and roof sheathing debris was light. Fire was the only cause of serious damage to machine tools in five steel-frame building, four of which were combustible. Three buildings were burned out and all their machine tools were seriously damaged because of the combustibility of building materials and contents and the congested areas in which the buildings were located.

e. Load-Bearing, Brick-Wall Buildings. Debris caused serious damage to only 5 percent of the machine tools in load-bearing, brick-wall buildings although 30 percent of the total floor area was structurally damaged. Two of the buildings sustained structural damage, but serious damage to machine tools occurred in only one because, by chance, there were no machine tools near the brick wall which was collapsed inward. One of the three load-bearing, brick-wall buildings was burned out and all its machine tools were seriously damaged because of the combustibility of building materials and contents and the congested area in which the building was located.

f. Weather Exposure. Exposure to weather caused slight damage to machine tools in buildings which were blast damaged but had no fire, and increased the degree of damage to machines which had already sustained heavy damage by fire. Rusting apparently was more severe on fire-damaged machine tools because all lubricants and paint had been burned off.

g. Mean Areas of Effectiveness (MAE). The number of machine tools in various types of buildings in the blast-affected area was much too small to permit calculation of reliable MAE's (Mean areas of effectiveness) for serious damage by blast and debris. The MAE for serious damage to machine tools by fire in combustible buildings was virtually the 4.4-square-mile, burned-over area of the city.

h. Poor target. The central portion of Hiroshima was a poor target for the atomic bomb from the standpoint of damage to machine tools because all large industrial plants were located on the outskirts.

i. Blast Versus Fire and Structural Damage. The total amount of serious damage to machine tools by blast and debris was small compared to serious damage by fire, and also compared to the structural damage by blast to the buildings in which they were housed.

j. Damage by Fire. Serious damage to machine tools by fire was primarily a result of the combustibility of the buildings in which they were housed. It is doubtful that fire would have caused serious damage generally to machine tools in modern noncombustible or fire-resistive buildings, of which there were none housing machines in the burned-over area.

k. No Blast Walls. There were no special walls around machine tools for protection against fragmentation, debris, and blast effects of high-explosive bombs.

l. Suppositions. The atomic bomb made no crater and evidently caused no earth shock. If an atomic bomb were detonated on or very near the ground, it is believed that all exposed precision machine tools within several hundred feet in all directions from the point of detonatioin would be totally or heavily damaged by the combined effects of cratering, earth shock, blast debris, and intense heat.

m. Protective Measures. The blast and debris hazard to machine tools can be most effectively limited by installing them in reinforced-concrete buildings of adequate strength and design to withstand the blast pressures of an atomic bomb, or by placing them in underground structures. Another alternative would be to install machine tools in steel-frame structures sheathed with a frangible material such as thin corrugated asbestos. The fire hazard to machine tools can be effectively limited by installing them in fire-resistive or noncombustible buildings containing a minimum of combustible contents. Most of the weather damage to machine tools could have been prevented by greasing or otherwise protecting them within the first few days after the atomic-bomb attack.

3. General

The major industries of Hiroshima were located on the south and southeastern outskirts of the city about 1½ miles from ground zero (GZ). The buildings themselves were practically unaffected by the atomic bomb which detonated over the heart of the city, and no damage was done to machine tools in them. Located within the area seriously affected by blast and fire were numerous small, light engineering shops and a few small, heavy engineering shops containing 2 to 40 machine tools. These small shops were engaged in the manufacture of products such as shell cases, fuses, pumps, gauges, gears, and torpedo parts. With few exceptions the plants were producing for the military. The machine tools were principally lathes, drill presses, shapers, and boring, grinding, shearing, pressing, and stamping machines.

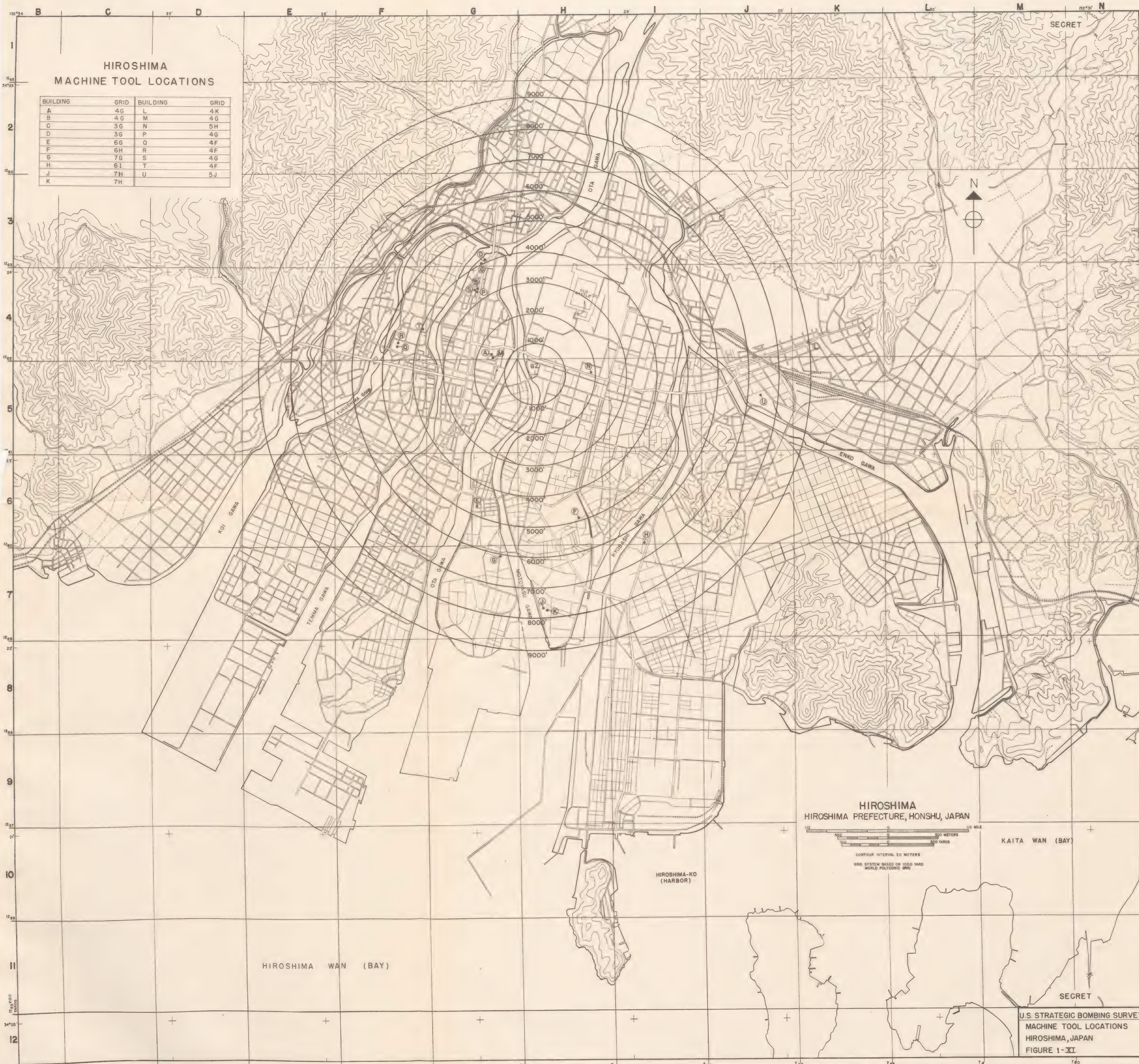
4. Analysis of Damage

Machine tools in 19 one-story buildings, locations of which are shown on Figure 1, were included in this study. Eleven of the buildings were wood-frame (Photos 1–13), five were steel-frame (Photos 14–19), and three were load-bearing, brick-wall structures (Photos 20–23). All wood-frame machine shops which were within the blast-affected area and not burned and a few typical wood-frame machine shops which were burned were included in the study. All steel-frame and load-bearing, brick-wall buildings containing machine tools in the blast-affected area were included in the study whether burned or not. There were no multi-story or reinforced-concrete buildings containing machine tools. All the buildings housing machine tools were combustible except one steel-frame corrugated-iron-sheathed building. Four of the nineteen buildings were outside the 4.4-square-mile burned-over area and were unburned, but were within 7,600 feet of GZ. An additional four buildings which were within the burned-over area were unburned. Twelve of the buildings sustained 100 percent structural damage, three sustained 18, 47, and 77 percent structural damage, respectively, and four sustained none. All machine-tool data have been listed in Table 1 and summarized graphically in Figure 2, including data on the buildings in which the machine tools were housed. Damage to machine tools has been classified in three categories: (1) total damage (TD)—damage which caused scrapping; (2) heavy damage (HD)—damage which could not be repaired by the normal maintenance staff; and (3) slight damage (SD)—damage which could be repaired by the normal maintenance staff. Damage to machine tools was caused by debris, fire, or subsequent exposure to weather. No instances

TABLE 1.—*Machine tool data*

Building	Grid	District from AZ (feet)	District from GZ (feet)	Occupancy	Plan area (square feet)	Stories	Building type	Building HE-V	Building fire-V	Building damage—Percent: Structural Blast	Structural Fire	Structural Mixed	Superficial Blast	Superficial Fire	Machine tool damage—Percent: Debris TD	Debris HD	Debris SD	Fire TD	Fire HD	Fire SD	Weather TD	Weather HD	Weather SD	All causes TD and HD
A	4G	2,600	1,600	Light engineering	1,200	1	Wood-frame	V4	C	100	0	0	0	0	15	0	10	70	15	0	0	0	0	100
B	4G	4,000	3,400	do	1,500	1	do	V4	C	100	0	0	0	0	0	10	5	60	30	0	0	0	0	100
C	3G	4,400	4,000	do	9,500	1	do	V4	C	77	NF		23		0	0	20				0	0	80	0
D	3G	4,500	4,100	Needle manufacturing	2,400	1	do	V4	C	100	0	0	0	0	0	5	5	90	5	0	0	0	0	100
E	6G	5,100	4,700	Light engineering	2,000	1	do	V4	C	100	0	0	0	0	0	0	15	65	35	0	0	0	0	100
F	6H	5,300	4,900	do	1,500	1	do	V4	C	100	0	0	0	0	0	0	10	80	20	0	0	0	0	100
G	7G	6,300	6,000	do	3,200	1	do	V4	C	100	NF		0		0	0	10				0	0	10	0
H	6I	6,800	6,500	do	3,500	1	do	V4	C	100	0	0	0	0	0	15	5	65	20	0	0	0	0	100
J	7H	7,800	7,500	do	3,200	1	do	V4	C	0	NF		100		0	0	0				0	0	25	0
K	7H	7,900	7,600	do	5,100	1	do	V4	C	0	NF		0		0	0	0				0	0	0	0
	4K	9,200	9,000	do	2,500	1	do	V4	C	0	100	0	0	0	0	0	0	75	25	0	0	0	0	100
M	4G	2,500	1,500	do	2,200	1	Steel-frame	V4	C	100	0	0	0	0	0	0	20	80	20	0	0	0	0	100
N	5H	2,700	1,800	do	1,300	1	do	V4	N	100	0	0	0	0	0	0	0	0	100	0	0	0	0	100
P	4G	3,900	3,300	do	2,600	1	do	V4	C	0	0	0	100	0	0	0	0	40	60	0	0	0	0	100
Q	4F	5,100	4,700	Heavy engineering	5,900	1	do	V4	C	18	NF		82		0	0	0				0	0	100	0
R	4F	5,100	4,700	do	9,300	1	do	V4	C	47	NF		53		0	0	0				0	0	100	0
S	4G	3,900	3,300	Light engineering	7,000	1	Brick, load-bearing steel-truss.	V4	C	100	0	0	0	0	0	0	15	50	50	0	0	0	0	100
T	4F	4,400	4,000	do	2,300	1	do	V4	C	100	NF		0		50	25	0				0	0	25	75
U	5J	7,800	7,500	do	21,400	1	do	V4	C	0	NF		0		0	0	0				0	0	20	0

AZ—Air zero; GZ—Ground zero; HE-V—High explosives vulnerability; TD—Total damage; HD—Heavy damage; SD—Slight damage; NF—No fire.



BUILDING	GRID	BUILDING	GRID
A	4G	L	4K
B	4G	M	4G
C	3G	N	5H
D	3G	P	4G
E	6G	Q	4F
F	6H	R	4F
G	7G	S	4G
H	6I	T	4F
J	7H	U	5J
K	7H		

of direct damage by blast were observed, although a few cases of slight damage were attributable to displacement of overhead shafting and belting. In Table 1, all damage attributable to debris has been recorded, but damage caused by subsequent fire and weather effects has been recorded only when the damage was more severe than the category of damage by debris. For example, when machines which were heavily damaged by debris were subsequently heavily damaged by fire, but not totally damaged, the damage was tabulated in the heavy-damage-by-debris category; and when machines which were heavily damaged by fire were subsequently slightly or heavily damaged by exposure to weather, the damage was tabulated in the heavy-damage-by-fire category. The high-explosive vulnerability of all buildings was V4 (reference tables) since all were one-story, shed-type structures and the area of each, with the exception of one, was less than 10,000 square feet. The relationship between machine-tool damage and building structural and fire damage is summarized graphically in Figure 3.

5. Machine Tools in Wood-Frame Buildings

a. Debris. Debris caused only a small amount of total or heavy damage to machine tools in wood-frame buildings. Although 7 of the 11 wood-frame buildings were 100 percent and 1 was 77 percent structurally damaged by blast, only 5 to 15 percent of the machine tools in 4 of these buildings were seriously damaged by debris. The apparent reason for the small amount of debris damage to machine tools was that, except close to GZ, the blast collapsed wood-frame buildings practically as units with lateral motion because of the instantaneous equal pressure exerted against the entire side facing the blast. As a result, the debris did not crash down hard but tended to slide across the tops of machines instead (Photos 4, 9, and 11). Serious damage which was caused by debris resulted mainly from heavy overhead shafting and pulleys striking the machines (Photos 1, 2, 5, and 8). A few machines were partly or completely overturned by mass movement of the buildings (sometimes possibly assisted by the belts from overhead pulleys which moved with the building frame), but only slight damage was done to a few machines (Photos 2, 6, and 10). Sixty-four percent of the total floor area of the wood-frame buildings was structurally damaged by blast as compared to only about 3 percent serious damage to machine tools by debris, although total serious damage to machine tools by all causes was 41 percent (Fig. 3).

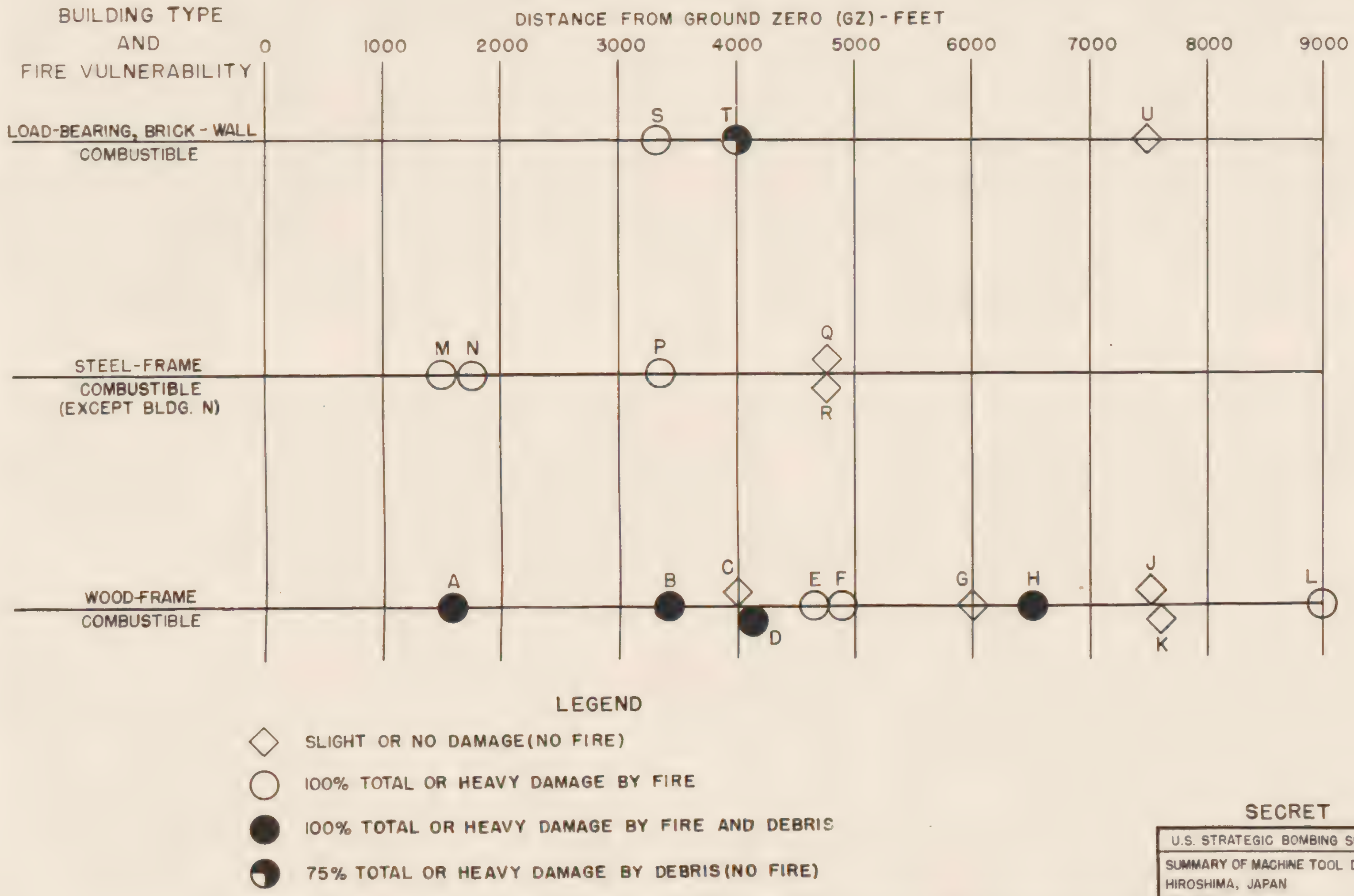
b. Fire. Fire was the principal cause of serious damage to machine tools in wood-frame buildings, accounting for 38 percent of the total number (Fig. 3). Seven of the 11 buildings studied were completely burned, and all of their machine tools were seriously damaged (Photos 1, 2, 5, 6, 7, 8, and 13). As shown in Figure 3, the total percent of machine tools seriously damaged (41 percent) was equal to the percent of the total floor area burned. Although 3 percent of the machine tools were totally or heavily damaged by debris, subsequent fire also damaged them, increasing the degree of damage. All machine tools in wood-frame buildings which burned sustained serious damage because, in addition to the frame, most floors and wall and roof sheathing were combustible, roof heights were generally low, and in most cases the walls or roofs were partly or completely collapsed placing the combustible debris close to the contents. In addition, the buildings had some combustible contents and were located in congested, combustible areas where all surrounding buildings burned, causing a generally high temperature in the area.

c. Weather. Most machine tools in structurally damaged and some in superficially damaged wood-frame buildings were exposed to the elements and in most cases no attempt was made to protect them, except that a few machines were protected with grease or sheets of corrugated iron (Photos 9 to 11). Rusting apparently was more severe on machine tools which had been exposed to fire, probably because all lubricants and paint had been burned off. Exposure to weather increased the degree of heavy damage to machine tools in burned buildings, and caused slight damage in blast-damaged buildings.

6. Machine Tool Damage in Steel-Frame Buildings

a. Debris. Debris was not the cause of total or heavy damage to machine tools in steel-frame buildings, although 2 of the 5 buildings of this type sustained 100 percent and two sustained 18 and 47 percent structural damage, respectively. The other building had light corrugated-asbestos wall sheathing which crumbled under the blast, and the steel frame was only superficially damaged although it was only 3,300 feet from GZ (Photo 17). There was no serious damage to machine tools in structurally damaged buildings because the blast caused

GRAPHIC SUMMARY OF CAUSE AND EXTENT OF DAMAGE TO MACHINE TOOLS



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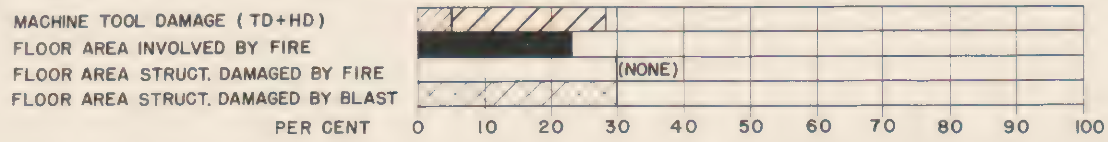
U.S. STRATEGIC BOMBING SURVEY
SUMMARY OF MACHINE TOOL DAMAGE
HIROSHIMA, JAPAN
FIGURE 2 - XI

SECRET

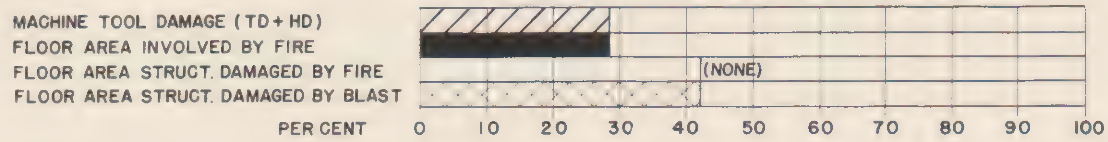
MACHINE TOOL DAMAGE IN RELATION TO BUILDING DAMAGE

(LIGHT MACHINE TOOLS IN ONE-STORY BUILDINGS)

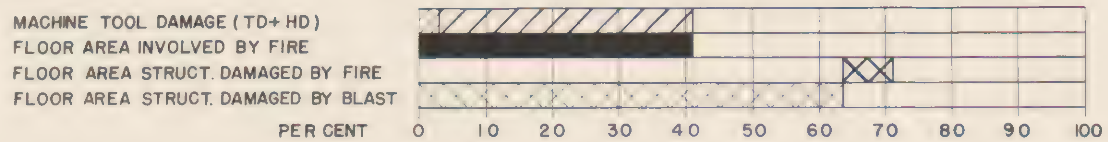
THREE LOAD-BEARING, BRICK-WALL BUILDINGS (3300-7500 FEET FROM GROUND ZERO)



FIVE STEEL-FRAME BUILDINGS (1500-4700 FEET FROM GROUND ZERO)



ELEVEN WOOD-FRAME BUILDINGS (1600-9000 FEET FROM GROUND ZERO)



LEGEND

TD - TOTAL DAMAGE

HD - HEAVY DAMAGE

- DAMAGE BY DEBRIS

- DAMAGE BY FIRE

SECRET

U.S. STRATEGIC BOMBING SURVEY

MACHINE TOOL DAMAGE VS. BLDG. DAM.

HIROSHIMA, JAPAN

FIGURE 3-XI

mass distortion of the steel frames without tearing loose heavy structural members, and wall- and roof-sheathing debris was too light to cause more than slight damage, and then only to machine tools in buildings relatively close to GZ. A few machine tools were partly overturned by mass movement of building frames (Photos 15 and 16). Forty-two percent of the total floor area of the five steel-frame buildings was structurally damaged by blast as compared to 28 percent serious damage to machine tools, none of which was caused by debris (Fig. 3).

b. Fire. Fire caused all serious damage to machine tools in the five steel-frame buildings, four of which were combustible and the other noncombustible. Three of these buildings, including the noncombustible one, were completely burned out (Photos 14–17). All machine tools were totally or heavily damaged in the burned buildings, the percentage of machine tools seriously damaged (28 percent) being equal to the percentage of floor area involved by fire (Fig. 3). Serious fire damage to machine tools resulted in the combustible buildings because floors and wall and roof sheathing were combustible; combustible debris was blown onto and around the machines; some of the contents were combustible; and the buildings were located in congested, combustible areas which were completely burned over. The machine tools in the noncombustible building were heavily damaged because the floor and some contents were combustible and exposing buildings burned close by on two sides.

c. Weather. Exposure to weather was the cause of slight damage to machine tools in two steel-frame buildings which had no fire (Photos 18 and 19), and increased the degree of damage to machine tools which had been heavily damaged by fire. As in wood-frame buildings, rusting of machine tools was much more severe in buildings which had burned than in ones which had been only blast damaged. Machine tools in these buildings were not given a coating of grease or otherwise protected from weather after the attack.

7. Machine Tools in Load-Bearing, Brick-Wall Buildings

a. Debris. Debris caused total or heavy damage to machine tools in only one of 3 buildings with load-bearing brick walls, accounting for only 5 percent of all machine tools in this type of buildings as compared to 23 percent total or heavy damage by fire (Fig. 3). This building and another one sustained complete structural damage by blast whereas the third sustained neither structural nor superficial damage. Thirty percent of the total floor area of the 3 buildings was structurally damaged. In the building in which total and heavy damage to machine tools occurred the brick wall which faced the blast and the steel roof trusses collapsed onto the machinery (Photo 20). Similarly, in the other building 100 percent structurally damaged by blast, the brick wall which faced the blast and the steel roof trusses were collapsed into the building (Photo 22), but, by chance, no machine tools were located close to the wall so the brick debris caused no damage. The steel trusses, which had lateral motion because the brick supporting walls collapsed away from the blast, came to rest on some presses but caused only slight damage (Photo 21).

b. Fire. Only one of the three load-bearing, brick-wall buildings had fire. This building was completely burned out and all the machine tools were totally or heavily damaged by fire alone, although the building was 100 percent structurally damaged by blast (Photos 21 and 22). The reasons for the serious damage to machine tools by fire were that the roof was completely collapsed, placing the wood-sheathing debris close to the machine; some of the contents were combustible; and the building was located in a congested, combustible area which was completely burned over.

c. Weather. Exposure to weather was the cause of slight damage to some machine tools in two load-bearing, brick-wall buildings which had no fire, and it increased the degree of damage to machines which had been heavily damaged in the building which burned. As in other types of buildings, rusting of machine tools was more severe in the building which burned than in the two which did not. No effort was made to protect the machine tools from the elements after the atomic-bomb attack.

8. Mean Areas of Effectiveness

a. Blast and Debris. The number of machine tools in various types of buildings (one-story wood-frame, steel-frame, and load-bearing, brick-wall structures) in the blast-affected area was much too small to permit calculation of reliable MAE's for serious damage (total or heavy) by blast and debris caused by detonation of the atomic bomb. Based upon observations in a few buildings, apparently blast and debris were most effective in causing serious damage to machine tools in load-bearing, brick-wall buildings, and least effec-

tive in steel-frame buildings. There were no machine tools in multistory buildings or in reinforced-concrete buildings.

b. Fire. The MAE for total or heavy damage to machine tools by fire in combustible buildings (one-story wood-frame, steel-frame, and load-bearing, brick-wall structures) was virtually the 4.4-square-mile area of the city which was burned, the radius of the MAE being about 6,250 feet. Only 4 buildings, all of which were combustible, containing machine tools within the burned-over area were not burned. There were machine tools in only one very small noncombustible building within the burned-over area. Although fire caused serious damage to the two machine tools in this building, it is doubtful that fire would have caused serious damage generally to machine tools in modern, noncombustible or fire-resistive machine shops, since serious fire damage to machine tools is dependent primarily upon the combustibility of the buildings in which they are housed.

9. Conclusions and Recommendations

a. The city of Hiroshima was a poor target for the atomic bomb from the standpoint of damage to machine tools because of the absence of concentrations of machine tools in the central part of the city. All large industrial plants were located peripherally on the south and southeastern outskirts of the city and were practically unaffected by the explosion of the atomic bomb.

b. The atomic bomb caused a small amount of serious damage to machine tools by blast and debris as compared to fire in one-story wood-frame, steel-frame, and load-bearing, brick-wall buildings (Fig. 3). There were no machine tools in multistory buildings or in reinforced-concrete buildings.

c. Only 3 percent of the machine tools in the 19 buildings of all types studied sustained serious damage by blast and debris, whereas the same buildings sustained 47 percent structural damage by blast.

d. Machine tools in steel-frame, lightly sheathed buildings are least likely to be seriously damaged by blast and debris, and in load-bearing, masonry-wall buildings are most likely to be seriously damaged (Fig. 3).

e. In wood-frame buildings, serious damage by debris appeared to have been caused mainly by overhead shafting and pulleys crashing down upon the machine tools. In view of the probability that belts from overhead shafting overturned or assisted in overturning machines, it is apparent that overhead shafting and other heavy equipment should be eliminated from buildings which are susceptible to mass distortion or collapse by blast.

f. Machine tools were overturned by mass movement of building frames, sometimes aided by belts from overhead shafting, because the machines were insecurely bolted to foundations, or foundations were light and were lifted by the machines. However, only slight damage was caused to the machine tools overturned, probably because the floors were wood or earth. Some heavy damage probably would have resulted if floors had been concrete.

g. The number of machine tools in various types of buildings within the blast-affected area was too limited to warrant calculation of MAE's for total or heavy damage by blast and debris.

h. The blast and debris hazard to machine tools can be most effectively limited by installing them in reinforced-concrete buildings of adequate strength and design to withstand the blast pressures of the atomic bomb, or by placing them in underground structures. Another alternative would be to install machine tools in steel-frame structures sheathed with a frangible material such as thin, corrugated asbestos.

i. The extent of damage which would be wrought upon machine tools by an atomic bomb detonated on or very near the ground is a matter of conjecture. The bomb detonated at Hiroshima made no crater and evidently caused no earth shock. If an atomic bomb were detonated on or very near the ground, it is believed that all exposed precision machine tools within several hundred feet in all directions of the point of detonation would be totally or heavily damaged by the combined effects of cratering, earth shock, blast, debris, and intense heat.

j. There were no special walls around machine tools for protection against fragmentation, debris, and blast effects of high explosive bombs. Although such protective walls constructed of loose bricks were found to have been very effective against high-explosive bombs in Europe, it is believed that they would have been generally ineffective against the action of the atomic bomb in Hiroshima for several reasons. In the first place, there was apparently no fragmentation hazard from the atomic bomb; secondly, mass distortion of building frames occurred instead of individual members being torn loose and blown through the

air by blast; thirdly, because of the high air burst of the atomic bomb, blast walls would not have shielded machine tools near GZ, and would have shielded them farther away from GZ only if the walls were as high or higher than the machines. Blast walls might have prevented some damage to machine tools in wood-frame and load-bearing, brick-wall buildings by protecting the machine tools from collapsing trusses, overhead shafting and brick walls, but on the other hand, debris from the protective walls themselves might have augmented damage.

k. The atomic bomb was effective in causing serious fire damage to machine tools in wood-frame, steel-frame, and load-bearing, brick-wall buildings. However, its efficiency on this score was attributable to the combustibility of the city as a whole and the buildings in which the machine tools were housed more than to the heat of the bomb itself. Machine tools were not damaged by flash heat from the bomb.

l. The percentage of serious damage to machine tools was closely related to the percentage of floor area involved by fire in the buildings in which they were housed (Fig. 3), all of which were combustible except one small noncombustible shop. It is doubtful that fire would have caused serious damage generally to machine tools in modern, noncombustible or fire-resistive machine shops.

m. All machine tools, although the number was small, were totally or heavily damaged within 3,500 feet from GZ (Fig. 2). All buildings within this distance from GZ were gutted by fire which was the principal cause of serious damage to machine tools.

n. The MAE for total or heavy damage to machine tools by fire in combustible buildings was virtually the 4.4-square-mile, burned-over area of the city.

o. The fire hazard to machine tools can be most effectively limited by installing them in fire-resistive or noncombustible buildings containing a minimum of combustible contents.

p. Electric motors were short-circuited and burned as a result of dust and light debris resulting from blast. In order to eliminate this hazard, electric motors should be dust-proof.

q. Exposure to weather caused additional damage to many machine tools which had already been damaged by debris or fire. Machine tools which had been exposed to fire effects were most severely rusted, probably because all lubricants and paint had been burned off. Most of the weather damage to machine tools could have been prevented by greasing or otherwise protecting them within the first few days after the atomic-bomb attack.

PHOTO 1–XI. Building A, 1,600 feet west of GZ, looking northwest. A wood-frame, light-engineering shop destroyed by blast. Debris broke casting of shear at left but casting was weak, having been cracked and welded previously. Fire burned combustible debris and seriously damaged remainder of machine tools.

PHOTO 2–XI. Building B, 3,400 feet northwest of GZ, looking west. A congested, wood-frame, light-engineering shop totally damaged by blast. All machine tools seriously damaged, caused mainly by fire which burned debris. Note partly overturned drill press and overhead line shafting thrown over wall away from blast.

PHOTO 3 XI. Building C, 4,000 feet northwest of GZ, looking west. A wood-frame building about 75 percent structurally damaged by blast. No serious damage to machine tools, no fire in building. Note light combustible debris on floor; machine tools unprotected from weather.

PHOTO 4–XI. Building C, 4,000 feet northwest of GZ, looking southwest. Shows wood truss resting on heavy machine at southwest corner of wood-frame building collapsed by blast. Only slight damage to machine. Note machine unprotected from weather. No fire in building.

PHOTO 5-XI. Building D, 4,100 feet northwest of GZ, looking southwest. A wood-frame, needle manufacturing plant destroyed by blast. Serious damage to machinery caused mainly by fire which burned combustible debris.

PHOTO 6-XI. Building E, 4,700 feet southwest of GZ, looking northwest. A wood-frame, light-engineering shop destroyed by blast. Serious damage entirely by fire which burned combustible debris. Note milling machine at right overturned when blast collapsed building. Press in center partly overturned in same manner.

PHOTO 7–XI. Building F, 4,900 feet southeast of GZ, looking southeast. A wood-frame, light-engineering shop structurally damaged by blast. Ensuing fire caused all serious damage to machine tools. Note line shafting resting on machines; building was shielded somewhat from blast and shafting apparently did not crash down.

PHOTO 8–XI. Building H, 6,500 feet southeast of GZ, looking northwest. A wood-frame, light-engineering shop structurally damaged by blast. Ensuing fire caused most of serious damage to machine tools. Note cracked concrete base of small lathe at left.

PHOTO 9-XI. Building G, 6,000 feet south of GZ, looking west. A wood-frame, light-engineering shop collapsed as a unit by blast (no fire). Wood trusses had lateral motion imparted by blast and came to rest on lathes, damaging them only slightly. These machine tools were given a protective coating of grease soon after the atomic-bomb attack.

PHOTO 10 XI. Building G, 6,000 feet south of GZ, looking south. A wood-frame machine shop collapsed by blast. Several machine tools (drill presses and shapers) inside north wall facing blast were overturned by mass movement of building frame. Machines were mounted on individual slabs of concrete which in some cases were uprooted by overturning of the machines. Only slight damage to machine tools by debris and exposure to weather. Note protective coating of grease on parts of machines.

PHOTO 11–XI. Building J, 7,500 feet south of GZ, looking east. A wood-frame machine shop superficially damaged by blast (no fire). Some machine tools slightly damaged by weather. Note corrugated-iron sheets on machines.

PHOTO 12–XI. Building K, 7,600 feet south of GZ, looking east. A wood-frame machine shop practically undamaged by blast (no fire). No damage to machine tools. Note tarpaulin over equipment at left.

PHOTO 13–XI. Building L, 9,000 feet east of GZ, looking north. A wood-frame, light-engineering shop destroyed by fire near edge of a completely burned, congested area. Serious fire damage to all machine tools. Note machines unprotected from weather.

PHOTO 14–XI. Building M, 1,500 feet west of GZ, looking north. A steel-frame, combustible machine shop structurally damaged by blast. Slight damage to machine tools by debris, but serious damage to all by fire. Entire surrounding congested area burned over.

PHOTO 15–XI. Building M, 1,500 feet west of GZ, looking east. Shows drill press partly overturned and small casting broken at the top by mass distortion of steel frame of building. All machine tools seriously damaged by fire.

PHOTO 16–XI. Building N, 1,800 feet east of GZ, looking north. A steel-frame, noncombustible repair shop structurally damaged by blast. Drill press and lathe seriously damaged by fire in combustible floor and contents. Note rubber tires on bicycles burned.

PHOTO 17-XI. Building P, 3,300 feet northwest of GZ, looking east. A steel-frame, combustible, light-engineering shop superficially damaged by blast. No damage to machine tools by blast or debris. Serious damage to all machine tools by fire in combustible debris and wood floor. Entire congested area burned over.

PHOTO 18–XI. Building Q, 4,700 feet west of GZ, looking east. A steel-frame, combustible, heavy-engineering shop structurally damaged at east end by blast. No damage to machine tools by blast or debris. No fire.

PHOTO 19–XI. Building R, 4,700 feet west of GZ, looking east. A steel-frame, combustible, heavy-engineering shop about one-half structurally damaged by blast. No damage to machine tools by blast or debris. No fire.

PHOTO 20–XI. Building T, 4,000 feet northwest of GZ, looking west. A small, combustible machine shop with load-bearing brick walls. South and east walls, which faced blast, and roof were collapsed into building by blast, totally or heavily damaging 75 percent of machine tools. Remainder of machine tools slightly damaged by weather. No fire.

PHOTO 21–XI. Building S, 3,300 feet northwest of GZ, looking west. A combustible, light-engineering shop with load-bearing brick walls completely collapsed by blast. Note steel trusses resting on presses; trusses had lateral motion imparted by blast and caused only slight damage to machines. Combustible roof debris and contents burned and caused serious damage to all machine tools.

PHOTO 22–XI. Building S, 3,300 feet northwest of GZ, looking north. A load-bearing, brick-wall machine shop completely collapsed by blast. Walls at right collapsed into building, but no machine tools were located near it. Steel trusses came to rest on machines but apparently did not crash down because of lateral motion imparted by blast, and only slight damage resulted. Fire caused serious damage to all machine tools.

PHOTO 23–XI. Building U, 7,500 feet east of GZ, looking east. A load-bearing, brick-wall, combustible machine shop practically undamaged by blast. No damage to machines by blast or debris. No fire. Slight damage to few machine by weather.

SECTION XII

DAMAGE TO BRIDGES

1. Summary

a. General. The atomic bomb detonated at Hiroshima, although it was an extremely powerful blast weapon, caused relatively little structural damage to the 81 important bridges. Scattered throughout the entire city, the bridges, 260 to 15,600 feet from ground zero (GZ), connected islands to islands and islands to mainland, forming an adequate and efficient bridge system. Not only did the bridges satisfy local transportation needs but they served also as overcrossings for the city services and utilities, and as a connecting link in the important Inland Sea coastal highway between Osaka and Shimonoseki (Fig. 1).

b. Fifty-seven of the 81 bridges were selected for detailed study on the basis of location, type, and use. The bridges selected varied in location from 260 to 12,200 feet from GZ. They comprised 19 timber, 15 concrete, and 23 steel bridges; and in use they were classified as railroad, street railway, highway, and pedestrian bridges, and aqueducts. No bridge damage resulting from the atomic bomb detonation was found beyond 7,600 feet from GZ (Table 1).

c. The 6 railroad bridges (5,580 to 8,480 feet from GZ), scattered along a circle at the foot of the hills in the northerly part of the city, were most distant from GZ. Strongly constructed of steel, they completely escaped damage except for radiant heat effects which, on 4 bridges, discolored to a minor degree the paint on girders on the side toward GZ. As an indirect effect, however, nearby fires resulting from the bomb explosion and debris thrown onto the tracks by blast closed the railroad lines to traffic for 2 days.

d. The nine street railway bridges (1,000 to 7,600 feet from GZ) were located principally in the heart of the city. They comprised two timber, one reinforced-concrete and six steel bridges. The damage incurred was limited to destruction by blast and fire of one timber bridge (4,670 feet from GZ), and blast damage to two steel bridges, one located 1,000 feet, and the other 4,670 feet from GZ which were closed to traffic for 3 and 30 days, respectively. Although closing the latter isolated the Hiroshima railroad passenger station and northeast part of the city from street railway service for 30 days, the total of all damage to bridges carrying street-railway tracks was not serious.

e. The 39 highway bridges (260 to 12,200 feet from GZ) comprising 14 timber, 15 concrete and 10 steel bridges, were most numerous as a class. They were scattered throughout the city and included bridges which were the nearest to, and the most remote from, GZ, so that the effects of the bomb on these bridges varied greatly. One steel bridge (1,190 feet from GZ) was totally collapsed by blast. Five steel bridges (260 to 7,600 feet from GZ) and five concrete bridges (4,270 to 6,450 feet from GZ) were damaged in extent varying from distorted and displaced decks and minor structural members to broken railings, curbs, posts and copings. Five timber bridges were structurally damaged by fire. Despite the fact that six highway bridges were totally damaged by the atomic bomb, the damage did not isolate any part of the city or seriously disrupt traffic.

f. All four pedestrian bridges (3,200 to 7,960 feet from GZ) were of timber construction. None was damaged by blast, but one (4,760 feet from GZ) was completely consumed by fire which spread from adjacent areas. The loss of this bridge caused no serious inconvenience, since traffic was rerouted over a structurally undamaged bridge within a distance of 900 feet.

g. Seven bridges (4 timber and 3 steel) which served as aqueducts and over-crossings for utilities were structurally damaged by blast and fire. All 4 timber bridges and 1 steel bridge were collapsed by blast and fire. The collapse or failure of the 7 bridges damaged 5,000 pairs of telephone wire in cables; one 16-inch and one 14-inch diameter water main; 840 feet of 12-inch diameter and 410 feet of 8-inch low pressure gas mains; and 270 feet of 6-inch diameter high-pressure gas mains. To place these utilities in operation would have required complete rebuilding of five overcrossings and repairs to the other two.

h. Vulnerability. Of the three types (timber, steel, concrete) studied in Hiroshima, timber bridges showed the least resistance to the effects of the atomic bomb. In terms of deck area, it was found that blast and fire totally damaged 33 percent of the 19 timber bridges, and 4 percent of the 23 steel bridges. None of the 15 concrete bridges suffered total damage. These percentages do not include such damage as broken railings, curbs, copings, and dislodged members, of which 5 concrete and 5 steel bridges showed a moderate amount (Table 4). There were insufficient data on bridges to compute reliable MAE's for all types. The analysis of data, however, led to the

below-listed conclusions on MAE's for structural damage by blast to bridges (graph 1).

Timber bridges, 2.4 square miles.
Steel bridges, 0 square mile.
Concrete bridges, 0 square mile.

i. In summation, impressive evidence of the ability of bridges to resist the forces of the Hiroshima atomic bomb (air-burst at 2,000 feet) was found in the facts that (1) 10 of 19 timber bridges studied were undamaged, (2) 10 of 15 concrete bridges had no damage, and (3) 14 to 23 steel bridges were undamaged (Table 4).

j. Since bridges are designed to resist heavy vertical loads, the fact that those near GZ received the blast forces largely in the direction of their greatest strength minimized the damage to them. Also, as evidenced by plate-girder Bridge 22 (260 feet from GZ and 2,020 feet from AZ), the orientation of the longitudinal center line toward GZ tended to decrease damage, e. g., the extended center line of Bridge 22 passed within approximately 50 feet of GZ; consequently, horizontal components of the blast forces were exerted in the direction in which the bridge was most resistant to such forces. At the same time the probability of damage from reflected blast waves was minimized. Bridge 24 (1,000 feet from GZ and 2,230 feet from AZ), with its extended center line passing approximately 650 feet from GZ, was similar in strength and construction to Bridge 22. It was, however, damaged more spectacularly and in greater degree due to reflected forces and skewed broadside exposure to horizontal components of the pressure wave. Negative pressures were generally unimportant in causing structural damage, but there was evidence that, at bridges within approximately 1,000 feet of GZ, there was an inrush of air following the initial positive blast.

k. It is probable that a bomb similar to the one used at Hiroshima, if detonated at an altitude lower than 2,000 feet, would cause appreciably more damage to bridges near GZ. But the height of detonation which would produce blast loadings exceeding the strength of the bridges is unknown. As discussed in the preceding paragraph, bridges near GZ had the advantage of receiving blast forces in the direction of their greatest strength, and, when oriented toward GZ, were most resistant to lateral forces and less liable to damage from reflected blast pressures. Therefore, the critical point of detonation for bridges would be one at which blast forces would be developed large enough to collapse the bridges by overloading the structural members. At lower altitudes of detonation it appears likely that the radius of damage at Hiroshima would have been decreased, due principally to the bridges being at ground elevation and therefore shielded to the maximum degree. The damage pattern would also probably have been less regular. Whether or not the advantage of shielding would have been offset by the larger horizontal components against the vertical bridge members is speculative.

l. Despite the great care exercised in segregating the damage to bridges attributable to the atomic bomb from the flood and typhoon damage occurring on 17 September and 5 October 1945, respectively, there is a distinct probability that the blast loadings from the bomb weakened some of the bridges and left them in a vulnerable condition. Flood and typhoon were credited with damaging to some degree nine timber, seven concrete and three steel bridges.

m. When considering the usefulness of the bridge system immediately following the detonation of the bomb, factors which should be considered in addition to actual damage to the system were the innumerable fires in areas adjacent to bridge entrances and exits, the debris from collapsed buildings which cluttered the bridge decks and roadways, and the general devastation and destruction which, depriving the city of the use of its bridges, temporarily trapped inhabitants on the islands without hope of immediate escape or relief from outside. Thirty hours elapsed before the first relief party penetrated the stricken area. Although the bridges generally resisted effectively the blast and fire from the bomb, lack of protection for the approaches and areas adjacent to the ends of the bridges rendered them almost useless at the time they were most needed.

n. Samples and Laboratory Testing of Materials. Members of the survey took samples of two cast-iron, railing-post sections from Bridges 23 and 24, and also paint samples from Bridges 26 and 27. These samples were brought back for the purpose of making laboratory tests of the materials, and of incorporating the results in the report as part of the data for future reference. The National Bureau of Standards tested the two cast-iron, railing-post sections and found them to correspond to ASTM Spec. A48–41, Class 20, the classification of lowest tensile strength fór gray iron castings. The relationships among the tensile, compressive and

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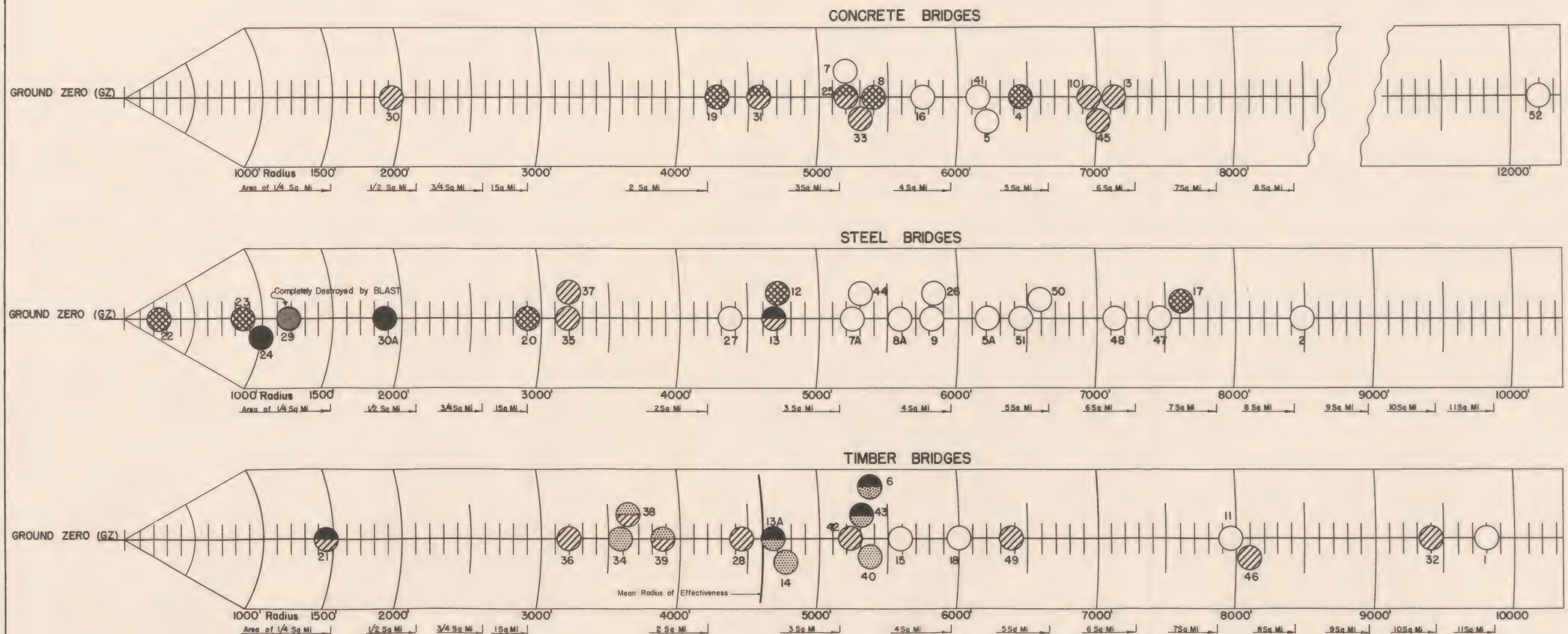
GRAPHIC SUMMARY OF DAMAGE TO BRIDGES

SHOWING LOCATION OF CONCRETE, STEEL AND TIMBER BRIDGES WITH RESPECT TO DISTANCE FROM GROUND ZERO (GZ).



LEGEND

- Blast Damage (Slight Structural)
- Superficial Blast Damage
- Flood Damage
- Fire Damage
- Blast & Fire Damage
- Blast & Flood Damage
- Flood & Fire Damage
- No Damage

ATOMIC BOMB BLAST DAMAGE
CONCLUSIONS

	MEAN AREA OF EFFECTIVENESS ABOUT GZ	MEAN RADIUS OF EFFECTIVENESS FROM GZ
TIMBER	2.4 SQ MI	4600 FT
STEEL	0.0 SQ MI	0 FT
CONCRETE	0.0 SQ MI	0 FT

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U.S. STRATEGIC BOMBING SURVEY
BRIDGE DAMAGE GRAPH
HIROSHIMA JAPAN
GRAPH I - XII

TABLE 1-XII.—*Bridge data*

Bridge features								Distances from zero point		Bridge damage (structural)					Remarks
Bridge number	Grid	Use of bridge	Type of construction	Width (feet)	Number of spans	Span length (feet)	Approximate length (feet)	GZ (feet)	AZ (feet)	Extent	Cause	Percentage type: Blast	Fire	Flood	
1	5K	Highway	Timber	20	13	30	390	9, 800	10, 000	None					Pedestrian use.
2	5J	Railroad	Plate girder	9	10	45	450	8, 480	8, 740	do					Single-track railroad.
3	5J	Highway	Concrete	24. 5	8	2 @ 33 6 @ 35	276	7, 130	7, 390	Severe	Flood			50	Pedestrian use, carrying 16″φ W. L.
4	5J	do	do	65. 5	5	Varies	250	6, 450	6, 750	None					Trolley traffic.
5	5J	do	do	26	5	2 @ 42 3 @ 40	204	6, 210	6, 510	do					Pedestrian use.
5A	5J	Aqueduct	Steel-truss	5. 3	5	44	220	6, 160	6, 470	do					Carrying 16″ φ W. L.
6	4T	Highway	Timber	17. 8	7	38	266	5, 370	5, 730	Complete destruction	Blast and fire	10	90		Pedestrian use.
7	4I	do	Concrete	23. 5	8	36	288	5, 200	5, 570	None					Do.
7A	4I	Aqueduct	Steel-truss	7. 3	4	2 @ 50 2 @ 95	290	5, 240	5, 600	do					Carrying 22″φ W. L.
8	4I	Highway	Concrete	18. 5	13	2 @ 39 11 @ 40	518	5, 390	5, 700	do					Pedestrian use.
8A	4I	Railroad	Girder, I-beam	18	1	20	23	5, 580	5, 900	do					Double-track railroad, underpass also.
9	3I	do	Plate girder	18	7	4 @ 57 3 @ 87	489	5, 730	6, 050	do					Double-track railroad.
10	3I	Highway	Concrete	18	7	1 @ 22 6 @ 47.5	307	6, 950	7, 250	Moderate	Flood			15	Pedestrian use, carrying 20″φ W. L.
11	2I	Pedestrian	Suspension	9	1	220	220	7, 960	8, 200	None					Timber deck, suspension cable.
12	5I	Highway	Plate girder	26	3	2 @ 59 1 @ 90	208	4, 700	5, 100	do					Pedestrian use, carrying 16″φ W. L.
13	5I	Trolley	Girder, I-beam	18	9	Varies	289	4, 670	5, 080	Moderate	Blast and flood	5		20	Double-track trolley.
13A	5I	do	Timber	18	9	33	307	4, 670	5, 080	Complete destruction	Blast and fire	10	90		Do.
14	5I	Pedestrian	do	19. 8	10	30	300	4, 760	5, 170	do	Fire		100		Foot bridge.
15	6I	Highway	do	19	15	Varies	309	5, 580	5, 900	None					Pedestrian use.
16	6I	do	Concrete	66	7	Varies	367	5, 750	6, 100	do					Do.
17	7H	do	Plate girder	72	9	Varies	544	7, 600	8, 870	do					Double track trolley, carrying 12″ φ W. L.
18	7G	do	Timber	19	16	28	448	6, 000	6, 300	do					Pedestrian use.
19	6G	do	Concrete	24	7	37	259	4, 270	4, 720	do					Pedestrian use, carrying 18″ φ W. L.
20	6G	do	Girder I-beam	15	9	2 @ 33 7 @ 30	276	2, 900	3, 450	do					Pedestrian use, carrying 16″ φ W. L.
21	5H	do	Timber	32. 8	10	29. 5	295	1, 450	2, 460	Complete destruction	Blast and flood	20		80	Pedestrian use.
22	5H	do	Plate girder	23	3	2 @ 43 1 @ 78	164	260	2, 020	None					Pedestrian use, carrying 16″ φ W. L.
23	4H	do	do	24	4	Varies	204	860	2, 170	do					Pedestrian use.
24	4H	do	do	72	7	Varies	407	1, 000	2, 230	Slight	Blast	10			Pedestrian use, double track trolley.
25	3G	do	Concrete	24	14	40	560	5, 200	5, 570	Moderate	Flood			15	Pedestrian use.
26	3H	Railroad	Plate girder	18	11	75	825	5, 750	6, 100	None					Double track railroad.
27	3G	Highway	Steel-arch	23. 5	1	200	200	4, 360	4, 790	do					Pedestrian use, carrying 10″ φ W. L.

TABLE 1–XII.—*Bridge data*—Continued

Bridge number	Grid	Use of bridge	Type of construction	Width (feet)	Number of spans	Span length (feet)	Approximate length (feet)	GZ (feet)	AZ (feet)	Extent	Cause	Blast	Fire	Flood	Remarks
		Bridge features						Distances from zero point		Bridge damage (structural)		Percentage type			
28	3G	Highway	Timber	65.7	6	33	198	4,430	4,840	Complete destruction	Flood			100	Pedestrian use, double track trolley.
29	5G	do	Timber-deck, steel-truss.	20	3	80	240	1,190	2,310	do	Blast	100			Pedestrian use, carrying 16″ φ W. L.
30	5G	do	Concrete	24	7	2 @ 45 5 @ 50	340	1,930	2,800	Severe	Flood			60	Pedestrian use.
30A	5G	Aqueduct	Steel-bowl-truss	5	7	50	350	1,880	2,750	Slight	Blast	10			Carrying 16″ φ W. L.
31	6G	Highway	Concrete	25	12	2 @ 29 10 @ 30	358	4,570	5,000	Severe	Flood			60	Pedestrian use, carrying 16″ φ W. L.
32	7E,	do	Timber	18	30	22	660	9,400	9,600	do	do			70	Pedestrian use.
33	6F	do	Concrete	18	12	2 @ 27 10 @ 36	414	5,300	5,650	do	do			70	Pedestrian use, carrying 16″ φ W. L.
34	5G	do	Timber	17.8	12	26	312	3,700	4,200	Complete destruction	Fire		100		Pedestrian use.
35	5G	Trolley	Girder, I-beam	16	8	33	264	3,190	3,750	do	Flood			100	Double track trolley.
36	5G	Pedestrian	Timber	10	7	25	175	3,200	3,760	do	do			100	6″ φ gas line.
37	5G	Highway	Timber deck, plate girder.	22.3	4	2 @ 44 2 @ 40	168	3,220	3,770	Severe	do			55	Pedestrian use, carrying 14″ φ W. L.
38	4G	do	Timber	12.1	11	30	330	3,750	4,250	Complete destruction	Fire and flood		50	50	Pedestrian use.
39	4G	do	do	16.8	16	26	415	3,880	4,390	do	do		30	70	Do.
40	3G	do	do	17.9	19	22	421	5,360	5,700	Severe	Fire		55		Do.
41	3F	do	Concrete	12	3	20	60	6,150	6,460	None					Do.
42	4F	do	Timber	17.9	14	30	421	5,100	5,490	Complete destruction	Flood			100	Do.
43	4F	do	do	18	16	25	400	5,180	5,510	do	Blast and fire	10	90		Pedestrian use, carrying 14″ φ W. L.
44	4F 5F	Trolley	Girder, I-beam	16	14	34	476	5,300	5,650	None					Double track trolley.
45	5E	Highway	Concrete	19	12	36	432	7,010	7,300	Moderate	Flood			15	Pedestrian use.
46	5E	do	Timber	13.1	10	22	220	8,090	8,350	Complete destruction	do			100	Do.
47	4E	Trolley	Girder, I-beam	16	10	34	340	7,450	7,700	None					Double track trolley.
48	4E	Highway	Plate-girder	24	4	60	240	7,130	7,400	do					Pedestrian use, 12″ φ and 14″ φ W. L.
49	3F	Pedestrian	Timber	3	11	15	163	6,380	6,650	Complete destruction	Flood			100	Foot traffic only.
50	3G	Railroad	Plate-girder	18	10	6 @ 35 4 @ 45	390	6,580	6,900	None					Double track railroad.
51	3G	do	do	18	2	33	66	6,450	6,780	do					Double track railroad, underpass also.
52	8J	Highway	Concrete	14.8	3	1 @ 43 2 @ 30	103	12,200	12,450	do					Pedestrian use.

shearing strengths were, however, about the same as in domestic cast irons of the same class, the carbon content being somewhat higher, and the silicon and manganese contents considerably lower. Results of paint tests have not yet been completed.

2. Description of Bridge System

a. Topographical and Historical. The city of Hiroshima was located upon the deltaic deposits of the Ota River, a relatively short, fast-flowing river which originated in the mountains north of the city. This delta was situated at the end of one of the few valleys running southwest to northeast across the Chugoku mountain range. The Ota River, flowing through the granite rocks of the mountains, flooded the delta, leaving deposits of earth and sand along the river beds. The beds, or branches, named from east to west, became known as the Enko-Gawa (River), Kyobashi-Gawa, Motoyasu-Gawa, Temma-Gawa, Fukushima-Gawa, and Yamate-Gawa. Eventually they separated the delta into the seven islands of Hiroshima (Fig. 1). Hiroshima was at the junction of the sea and land routes connecting Kyoto, Osaka, and Shimonoseki, and the northerly transmountain route to the coast of the Japan Sea. Since early times much importance had been attached to Hiroshima as a communications center, as well as the military and political headquarters of the Chugoku district.

b. Growth of Bridge System. The main thoroughfare was originally laid out around the foot of the mountain range in a semicircle convex northward and kept at a ground elevation above the dangers of flood and tide. Today the Sanyo line of the government railways follows the old highway in its route through Hiroshima toward Shimonoseki, using Bridges 9, 26, and 50 (Fig. 1) to cross the Kyobashi, Ota, and Yamate Rivers, respectively. As the city spread southward with the land reclamation projects which extended the islands seaward, surface communications from island to mainland and island to island required an ever-increasing number of bridges to accommodate not only the peak population of 380,000 persons in Hiroshima, but also the traffic passing through the city on the Inland Sea coastal highway.

c. Flood Effects on the System. A factor of prime importance in the development of the bridge system was the annual flood stages which the Ota River and its branches reached during the typhoon season from May through October. During these months the rivers frequently rose as much as 15 feet above normal mean high water and caused severe damage along their six beds by washing away the alluvial deposits from around the footings of the piers and bents to such an extent (as deep as 30 feet below normal grade) as frequently to impair the structural safety of the bridges and close them to traffic. In the Hiroshima area foundation soils were of a sandy nature, rock bottom being seldom encountered. To protect against erosion, the foundations of piers for steel and reinforced-concrete bridges were carried by concrete caissons to depths of approximately 30 feet below the river bed. The typhoons of 17 September and 5 October 1945 caused considerable additional damage to the bridges which had undergone the atomic-bomb attack on 6 August.

d. Selection of Bridges for Study. Of the many bridges found in Hiroshima by the team upon its arrival on 14 October 1945, 57 were selected for study in connection with physical damage resulting from the atomic-bomb attack. In this selection, primary considerations were given to location, use, and construction. The bridges (Fig. 1) ranged from 260 to 12,200 feet from ground zero (GZ) and were scattered throughout an approximate area of 12 square miles. In use, they were classified as railroad, street railway, highway, pedestrian, aqueduct, and mixed. The railroad bridges were principally in the northerly part of the city, the street railway bridges in the center, and the others distributed over the city. Of the 57 bridges studied, 23 were steel, 19 timber, and 15 reinforced concrete.

e. Ownership and Maintenance. At the start of the survey no estimate of damage had been prepared by the governmental agencies, but repairs to some damaged bridges were in progress, and others were scheduled. Most plans and records showing conditions prior to 6 August had been destroyed by the atomic-bomb holocaust. However, according to the opinion of the city engineer, approximately 80 percent of all bents and piers of the city-owned bridges were in good condition prior to the attack. The city had also repaired all damage from the 1944 flood and the remaining portions of the bridges had been checked over by the bridge department of the city. All railroad bridges maintained by the Japanese government were in excellent condition and all the highway bridges maintained by the prefectural government were in a good state of maintenance. The bridges carrying double-track street railways

maintained by the Hiroshima Electric Railway, Inc., were also in good condition. In November 1945, at the time of the survey, as the rate of return of residents increased, several bridges were under repair and the city engineers were planning to repair such others as was necessary to accommodate the flow of traffic along a northerly and southerly route through Hiroshima in order to prevent traffic bottlenecks in the city. Under consideration were Bridges 19, 31, 33, 45, and 46 which accommodated the southerly route and Bridges 37, 43, and 48 which accommodated the northerly one. In addition, the street-railway company had planned to make whatever repairs were deemed necessary to their own bridges. Bridge 13, the most important, had been under repair since before 12 October 1945.

f. Bridge Design. Inasmuch as most of the records of Hiroshima were burned or destroyed, little information was obtainable regarding the design of the bridge structures. Therefore, it was necessary to consult other sources, such as the Hiroshima Electric Railway, the city engineers, the prefectural government engineers and the government railroad officials, in searching for design standards and other pertinent information. From the few records available, and in many cases from memory, these agencies furnished much of the data incorporated in this section. Verified and supplemented by observation, interrogation, and inspection of documents, the data established that four principal ownerships of bridges existed in Hiroshima and that each differed somewhat from the others in design practice. In most cases the differences were explained by bridge use, rather than by official prerogatives. All the design criteria are discussed in the following paragraphs.

(1) *Bridge Use.* In the target area the bridges varied widely in use. Of the 57 studied, 39 were used to carry highway traffic (4 accommodated both highway and street-railway traffic); 5 were street-railway bridges; 6 carried railroads; 3 were used as aqueducts; and 4 were for the use of pedestrians. One of the pedestrian bridges was unique, being a Japanese Army suspension bridge with steel cables and timber deck.

(2) *Loading.* Timber bridges were designed for a single concentrated load of 12 to 15 tons per traffic lane. The city engineers did not know whether or not the timber bridges were designed for uniform loadings, earthquake, wind, or flood resistance. Timber piles were driven to a 4-ton capacity at a depth of approximately 6 feet below river beds by a pile driver with a 3.28-foot drop and a 0.3-ton drop-hammer when concrete foundations for the timber piles were omitted. In some cases a concrete foundation approximately 10 feet deep, 6 feet wide, and 12 to 20 feet long was constructed around pile bents. The length depended on the number of timber piles per bent. The piles were from 10 to 12 inches in diameter, approximately 30 feet long and extended into the concrete about 1.5 feet below the top of the foundation. Reinforced-concrete and steel-girder highway bridges were designed for a uniform load of 100 pounds per square foot. Impact was taken as 30 percent of the live load. Concentrated loads of 12 tons per girder were taken as design loads for steel bridges and 12 to 15 tons per traffic lane were taken for concrete bridges. The prefectural-owned bridges (Table 3) were designed for earthquake resistance after 1922. Interrogation of the prefectural government engineers indicated that earthquakes were very light and rare in the Hiroshima area. Nevertheless, earthquake resistance was taken into consideration for design purposes by allowing 15 percent of the dead load as the overturning force for steel-plate girders and 30 percent of the dead load as the overturning force for concrete piers acting at their respective center heights. Information did not indicate whether these bridges were designed for wind and flood resistance (Fig. 7). Railroad bridges were designed for Cooper's E–40 live load. No other information could be secured through interrogation in regard to design data. However, interrogation did disclose that the railroad engines were known as class D–51, weighing approximately 77 tons, and class D–52, weighing approximately 85 tons. The largest passenger car had a net weight of 35 tons and a gross weight of 50 tons, while the largest freight car had net and gross weights of 27 and 50 tons, respectively. Street-railway bridges carried a double-track railway. These bridges were designed for a total load of 26 tons which included earthquake resistance, passenger loading, and weight of street car. No other information in regard to design data was available except that, through interrogation, engineers stated that both the earthquake-resistance factor and the distributed load produced by the passengers in streetcars were reduced to equivalent concentrated loads for design. For purposes of design, a total load of 3.25 tons per streetcar wheel

TABLE 2.—*Street-railway bridges (schedule of materials)*

Description	Temma-Gawa Bridge (Bridge 35) (typical)					
	Section and weight (per linear foot)	Length		Weight per piece (pounds)	Number required for bent	Total weight (pounds)
		Feet	*Inches*			
I-beams	15 by 5 inches by 42 pounds	23	0	966	4	3, 864. 00
Angles	6 by 6 by 7/16 inches by 17.2 pounds	18	6	318. 2	2	634. 40
Do	do	18	0	309. 6	2	619. 20
Do	6 by 6 by 3/8 inches by 14.9 pounds	1	0	14. 9	32	476. 80
Do	3½ by 3 by 3/8 inches by 7.9 pounds	12	9	100. 73	2	201. 46
Do	do	12	3	96. 78	2	193. 56
Plates	24 by 3/8 inches by 30.6 pounds	2	6	76. 50	4	306. 00
Do	18 by 3/8 inches by 22.96 pounds	2	0	45. 92	4	183. 58
Do	15 by 3/8 inches by 19.14 pounds	1	6	28. 71	8	229. 68
Do	9 by 3/8 inches by 11.48 pounds	2	3¾	26. 55	2	53. 10
Rivet	¾ inch in diameter			0. 123	792	97. 42
Total weight per bent						6, 861. 31

was used. The company used two types of cars known as *A* car, weighing 18 tons (empty) and *B* car, weighing 14.7 tons (empty). In bridge design, cars *A* and *B* were assumed to weigh 26 tons fully loaded. The designers also assumed that a car when fully loaded would carry 160 persons. Each person was assumed to weigh 111 pounds and the approximate total passenger load was, therefore, 8.8 tons per car (Fig. 7).

(3) *Stresses.* The working stresses for timber bridges were not ascertainable. It was established, however, that working stresses of 16,000 pounds per square inch were used for steel and 640 pounds per square inch for concrete. The reinforced-concrete bridges were designed for concrete having an ultimate strength of 2,000 pounds per square inch in compression and for working stresses as follows: Tension, 64 pounds per square inch; shear, 64 pounds per square inch; compression, 640 pounds per square inch; compression in flexure, 640 pounds per square inch; except that prefectural government engineers used 500 pounds per square inch for concrete in compression.

g. Construction. Generally, the design, details, and arrangements for timber, concrete, steel-plate-girder, and rolled-section I-beam bridges used for both highway and street-railway traffic appeared to be below United States standards. The steel-plate-girder bridges for railroad traffic and steel-truss aqueducts compared favorably with similar structures in the United States.

(1) *Timber Bridges.* Field investigations showed that floor beams were not used and that stapled connections were used instead of bolts. Connections were not rigid over pile bents and bolster plates were placed directly beneath timber girders. Diagonal bracing for timber piling was insufficient. Rough log members were used in several bridges instead of dimension timber (Fig. 19).

(2) *Steel Bridges* employed girders haunched at supports as a general practice, and the continuity of spans was discarded in favor of cantilever design, due to poor foundations and piers which frequently settled. Rocker plates were used in some bridges at supports (Figs. 3 and 4).

(3) *In Reinforced-Concrete Bridges* haunching of girders at supports was common practice and cantilever design was substituted for span continuity over supports because of poor foundations and piers which frequently settled. Floor beams were not used. However, a greater number of closely spaced, concrete longitudinal beams was employed, thereby transmitting the deck loads directly to the abutments and bents. The construction of railings, ornamental posts, caps, copings and curbs would have been comparable with United States standards of construction if they had been properly anchored, keyed or doweled to the structures (Photos 13 and 36, and Fig. 8). Interrogation and inspection showed that the splicing of reinforcing bars was not practiced.

h. Materials. In general, the quality of materials appeared to be below United States standards. An exception was the steel employed in bridge structures which in size and appearance were comparable with United States standards.

(1) *Timber.* Field inspections showed that timber materials were considerably below United States standards. No evidence indicated that timber was treated with creosote or other preservatives. Dimensions were not normally of commercial sizes, and in many cases rough logs were used in the structures. In no case did the team find that timber bridges had received a protective coat of paint.

(2) *Concrete.* The aggregates used for concrete were sand and gravel from the local river beds, the former being unscreened. Gravel, however, was screened in an attempt to obtain some gradation, with maximum size stones of 2 to 3 inches. The cement was manufactured and obtained from the Ube Cement Co. and the Oroda Cement Co., both located in Tamaguchi Prefecture. Some cement was obtained from the nearby Asano Cement Co.

(3) *Steel.* Sizes of bars varied from 1/4 to 1 1/4 inches in diameter for steel reinforcing. Reinforcing for deck slabs varied from one-fourth to five-eighths inch in diameter. Stirrups were of various types and sizes. Temperature reinforcement was not used nor were square steel rods. Deformed reinforcing bars were not used principally because they were 50 percent more costly than plain bars. Rolled-steel I-beams were of standard sizes, reinforced against buckling by diaphragms and angle stiffeners. All materials (Table 2) were usually of medium steel and appeared to be comparable with United States standards. Steel received one shop coat of red-lead paint before shipment, and protective field coats later. A cast metal sign fastened to the face of the girders of railroad Bridge 51 showed the shipment and manufacturing of the materials as follows (Photo 109):

> Materials: Angles, IJG Steel Works, Kawasaki Zosenshokobe.
> Plate: Asano Zosen Seihambu.
> Rivets: Asano Rokuro Seikosho.

3. Analysis of Damage

a. Chronology and Use of Data. In assessing the damage to Hiroshima by the atomic bomb a difficult problem was to distinguish between bomb damage and flood and typhoon damage which came later. Since this complexity of damage was especially evident in the bridge system, it was felt that a chronological consideration of damage incidents and other data would serve as a valuable check list. Therefore, the cause and extent of damage to each bridge was established only after it had been carefully considered in relation to each of the following:

(1) Preattack air photos, dated 13 April 1945.

(2) Atomic-bomb damage of 6 August 1945.

(3) Postattack air photos, dated 7 August 1945.

(4) Flood damage of 17 September 1945.

(5) Flood and typhoon damage of 5 October 1945.

(6) Field observation from 14 October through 24 November 1945.

(7) Japanese drawings and documents.

(8) Interrogation of eyewitnesses and officials.

It is noteworthy that in the interval between the dropping of the atomic bomb and the arrival of the team two months later there occurred two severe storms, of which at least one had an intensity such as would be encountered only once in perhaps 50 or 100 years. These storms, unfortunately, destroyed much evidence of bomb action to bridges when they washed away the damaged structures.

b. Method of Analysis. Each of the 57 bridges selected for study was numbered and its location in relation to the point of detonation of the bomb (air zero, or AZ), and the point on the ground directly below AZ (ground zero, or GZ) was established (Fig. 1). Each individual bridge was then studied in detail with respect to its use, design, materials, special features, strength, quality of construction, cause of damage and extent of damage. Photographs of the bridges were taken to show the condition of the structures at the time of the field survey.

c. Definition of Terms. The damage, resulting from many causes occurring at different times, had left an analysis problem of considerable complexity. Therefore, for assessment, evaluation, and tabulation, the following classifications of damage was adopted by the survey.

(1) *Total Damage.* Damage requiring replacement of the entire bridge, or from 90 to 100 percent of spans and piers or bents.

(2) *Severe Damage.* Damage to the major part of the structure, requiring replacement of between 50 and 90 percent of the spans and piers or bents.

(3) *Moderate Damage.* Damage to the spans, piers or bents that could be repaired in a relatively short time; structural damage requiring replacement of between 10 and 15 percent of the spans and piers or bents.

TABLE 3.—*Prefectural government bridges*

Bridge No.	Type	Use	Approximate year constructed	Earthquake-resistance design	Remarks
5	Concrete	Highway	1925	Yes	NOTE.—(1) After the year 1922, all prefectural government bridges were designed for earthquake resistance.
8	do	do	1933	Yes	(2) Some of these bridges were also maintained by other agencies of Hiroshima.
12	Plate girder	do	1927	Yes	(3) NK=Not known.
16	Concrete	do	1935	Yes	
17	Plate girder	do	1925	Yes	
20	Girder I-beam	do	1921	No	
22	Plate girder	do	1925	Yes	
24	do	do	1931	Yes	
25	Concrete	do	1932	Yes	
27	Steel-arch	do	1922	No	
29	Steel-truss	do	1890	No	
32	Timber	do	NK	No	
37	Plate girder	do	1926	Yes	
43	Timber	do	1920	No	
48	Plate girder	do	1925	Yes	

(4) *Slight Damage.* Damage necessitating a minimum of repair to open the bridge to traffic; structural damage requiring replacement of between 0 and 10 percent of the spans and piers or bents.

d. Damage to Timber Bridges. Examination was made of 19 bridges of timber construction, of which 8 were either partly damaged or totally damaged by fire; but 3 (Bridges 6, 13, and 43) were initially damaged by blast; 2 (Bridges 38 and 39) were initially damaged by fire and later totally damaged by flood; one (Bridge 40) was severely damaged by fire only; and 2 (Bridges 14 and 34) were totally damaged by fire. Therefore, of the 19 timber bridges, 6 (Bridges 28, 32, 36, 43, 46, and 49) were partly or completely damaged by flood, 8 (Bridges 6, 13A, 14, 34, 38, 39, 40, and 43) by fire, 1 (Bridge 21) by blast and flood but initially by blast, and 4 (Bridges 1, 11, 15, and 18) were undamaged. The timber bridges were located from 1,450 feet (Bridge 21) to 9,800 feet (Bridge 1) from GZ. For details and sketches, Figures 19 and 20.

(1) *Bridge 1* (9,800 feet from GZ and 10,000 feet from AZ) was the most remote bridge studied. This bridge suffered no damage (Photos 1 and 2).

(2) *Bridge 6* (5,370 feet from GZ and 5,730 feet from AZ). The approximate midportion of this bridge was slightly damaged initially by blast and later was totally damaged by fire (Photo 11).

(3) *Bridge 11* (7,960 feet from GZ and 8,200 feet from AZ) suffered no damage (Photos 19–23).

(4) *Bridge 13A* (4,670 feet from GZ and 5,080 feet from AZ). The span adjacent to the west abutment was slightly damaged initially by blast and later the whole bridge was totally damaged by fire (Photos 31 and 32).

(5) *Bridge 14* (4,760 feet from GZ and 5,170 feet from AZ) was totally damaged by fire (Photo 33).

(6) *Bridge 15* (5,580 feet from GZ and 5,900 feet from AZ) suffered no damage (Photo 34).

(7) *Bridge 18* (6,000 feet from GZ and 6,300 feet from AZ) suffered no damage (Photo 37).

(8) *Bridge 21* (1,450 feet from GZ and 2,460 feet from AZ) was the nearest timber bridge to GZ. This bridge suffered slight structural damage. Spans at approximately the bridge center were totally damaged by the blast which also weakened the remaining timber spans, damaged the deck and totally damaged part of the timber railings along both sides of the bridge structure. At a later date this bridge was totally damaged by flood with the exception of part of one span adjacent to the west abutment (Photo 42).

(9) *Bridge 28* (4,430 feet from GZ and 4,840 feet from AZ) was totaly damaged by flood (Fig. 19, and Photo 76).

(10) *Bridge 32* (9,400 feet from GZ and 9,600 feet from AZ). The approximate middle portion of the bridge was severely damaged by flood (Photo 88).

(11) *Bridge 34* (3,700 feet from GZ and 4,200 feet from AZ) was totally damaged by fire (Photo 90).

(12) *Bridge 36* (3,200 feet from GZ and 3,760

feet from AZ) was totally damaged by flood (Photo 93).

(13) *Bridge 38* (3,750 feet from GZ and 4,250 feet from AZ). Initially the westerly half of the bridge was severely damaged by fire spreading from adjoining areas and later was totally damaged by flood (Photo 95).

(14) *Bridge 39* (3,880 feet from GZ and 4,390 feet from AZ). The easterly half of the bridge was initially moderately damaged by fire spreading from adjoining areas and later was totally damaged by flood (Photo 96).

(15) *Bridge 40* (5,360 feet from GZ and 5,700 feet from AZ). The northerly portion of this bridge was severely damaged by fire (Photo 97).

(16) *Bridge 42* (5,100 feet from GZ and 5,490 feet from AZ) was totally damaged by flood (Photo 99).

(17) *Bridge 43* (5,180 feet from GZ and 5,510 feet from AZ). The approximate midspan of this bridge was slightly damaged initially by blast and fire and later was totally damaged by flood (Photo 100). NOTE.—A new timber bridge was constructed.

(18) *Bridge 46* (8,090 feet from GZ and 8,350 feet from AZ) was totally damaged by flood (Photo 103).

(19) *Bridge 49* (6,380 feet from GZ and 6,650 feet from AZ) was totally damaged by flood (Photo 106).

e. Damage to Reinforced-Concrete Bridges. A study was made of 15 reinforced-concrete bridges (3, 4, 5, 7, 8, 10, 16, 19, 25, 30, 31, 33, 41, 45, and 52) (Fig. 1). They varied from 1,930 to 12,200 feet from GZ. Bridge 52, 12,200 feet from GZ, was the most remote of all the bridges studied. None of the reinforced-concrete bridges was structurally damaged by the atomic bomb. Several bridges, however, did suffer superficial damage from bomb effects, such as broken or damaged railings, dislodged ornamental posts, caps, and coping curbs. Of the 15 reinforced-concrete bridges, 5 (3, 10, 30, 33, and 45) were damaged by flood only; 3 (4, 8, and 19) suffered superficial damage by blast; 2 (25 and 31) suffered damage by flood and later received superficial damage by blast; and 5 (5, 7, 16, 41, and 52) were undamaged. For sketches, Figures 2–6, inclusive.

(1) *Bridge 3* (7,130 feet from GZ and 7,390 feet from AZ). The spans and piers adjacent to the south abutment were severely damaged by flood (Photos 4–7).

(2) *Bridge 4* (6,450 feet from GZ and 6,750 feet from AZ). This bridge suffered no structural damage but received superficial damage from the blast which blew off the northwest corner concrete railings (Photo 8).

(3) *Bridge 5* (6,210 feet from GZ and 6,510 feet from AZ) suffered no damage (Photo 10).

(4) *Bridge 7* (5,200 feet from GZ and 5,570 feet from AZ) suffered no damage (Photo 12).

(5) *Bridge 8* (5,390 feet from GZ and 5,700 feet from AZ). This bridge suffered no structural damage but received superficial damage from the blast which blew off the concrete railings along both sides (Photo 13).

(6) *Bridge 10* (6,950 feet from GZ and 7,250 feet from AZ). The spans and piers adjacent to the south abutment were moderately damaged by flood (Photo 18).

(7) *Bridge 16* (5,750 feet from GZ and 6,100 feet from AZ) suffered no damage (Photo 35).

(8) *Bridge 19* (4,270 feet from GZ and 4,720 feet from AZ). This bridge suffered no structural damage but received superficial blast damage indicated by dislodged ornamental posts (Photos 38 and 38A).

(9) *Bridge 25* (5,200 feet from GZ and 5,570 feet from AZ). The fourth bent from the south abutment was completely washed out by flood, but the bridge continued to carry unrestricted traffic. It also received superficial damage when blast blew off the concrete coping along both sides and slightly damaged the railing balusters directly over each pier (Photo 71 and Fig. 13).

(10) *Bridge 30* (1,930 feet from GZ and 2,800 feet from AZ), the nearest concrete bridge to GZ, was severely damaged by flood only (Photos 81–84 and Fig. 16).

(11) *Bridge 31* (4,570 feet from GZ and 5,000 feet from AZ) suffered severe damage by flood (Photo 87).

(12) *Bridge 33* (5,300 feet from GZ and 5,650 feet from AZ) suffered severe damage by flood (Photo 89).

(13) *Bridge 41* (6,150 feet from GZ and 6,460 feet from AZ) suffered no damage (Photo 98).

(14) *Bridge 45* (7,010 feet from GZ and 7,300 feet from AZ). The spans and bents adjacent to the east abutment were moderately damaged by flood (Photo 102).

(15) *Bridge 52* (12,200 feet from GZ and 12,450 feet from AZ) suffered no damage. This bridge

was the most distant bridge studied from GZ (Photo 110).

f. Damage to Steel Bridges. A study was made of 23 steel bridges (2, 5A, 7A, 8A, 9, 12, 13, 17, 20, 22, 23, 24, 26, 27, 29, 30A, 35, 36, 37, 44, 47, 48, 50, and 51) which ranged from 260 to 7,600 feet from GZ. Bridge 22 was the nearest to GZ, being only 260 feet therefrom, while Bridge 17 was the most distant steel bridge from GZ, being at 7,600 feet. Of 23 bridges studied, 1 (Bridge 29) was totally damaged by blast; 2 (24 and 30A) suffered slight structural damage by blast; 5 (12, 17, 20, 22, and 23) received superficial blast damage; 5 (9, 26, 27, 50, and 51) suffered no structural damage, but bomb effects were indicated by discoloration of the old paint on the steel members facing the direction of the blast; 1 (13) was initially damaged by blast and later moderately damaged by flood; 1 (37) was severely damaged by flood; 1 (35) was totally damaged by flood; and 7 (2, 5A, 7A, 8A, 44, 47, and 48) were undamaged. For sketches, Figures 2–6, inclusive.

(1) *Bridge 2* (8,480 feet from GZ and 8,740 feet from AZ) suffered no damage (Photo 3).

(2) *Bridge 5A* (6,160 feet from GZ and 6,470 feet from AZ) suffered no damage (Photo 10).

(3) *Bridge 7A* (5,240 feet from GZ and 5,600 feet from AZ) suffered no damage (Photo 12).

(4) *Bridge 8A* (5,580 feet from GZ and 5,900 feet from AZ) suffered no damage (Photo 14).

(5) *Bridge 9* (5,730 feet from GZ and 6,050 feet from AZ) suffered no structural damage but bomb effects resulted in the discoloring of the old paint on the steel members along the south side facing the flash. The north side was unaffected (Photos 15–17 and Fig. 17).

(6) *Bridge 12* (4,700 feet from GZ and 5,100 feet from AZ). This bridge suffered no structural damage but received superficial blast damage indicated by dislodged stone ornamental posts at its southwest corners (Photos 24, 25, and 26).

(7) *Bridge 13* (4,670 feet from GZ and 5,080 feet from AZ) was damaged by blast and flood. Initially this bridge suffered slight damage by blast, especially to the bents supporting the center portion of the bridge, and to the I-beam girders located at the approximate bridge center. At a later date it was moderately undamaged by flood (Photos 27–30 and Fig. 18).

(8) *Bridge 17* (7,600 feet from GZ and 8,870 feet from AZ). This bridge suffered no structural damage, but received superficial blast damage, both concrete railings of the main spans being totally damaged. The railings of the approach spans were not damaged by blast (Photo 36). Thiswas the most remote plate-girder bridge from GZ.

(9) *Bridge 20* (I-beam girder, 2,900 feet from GZ and 3,450 feet from AZ). This bridge suffered no structural damage by blast which, however, dislodged ornamental corner posts (photos 39, 40, and 41).

(10) *Bridge 22* (260 feet from GZ and 2,020 feet from AZ). Of plate-girder design, this was the nearest bridge to the zero points. It had four steel longitudinal girders arched at the center and haunched at their supports. The piers were concrete, faced with masonry. The roadway deck was of reinforced concrete with asphalt-wearing surface. The ornamental stone posts, two at east and west abutments and two at each river pier, were connected by concrete railings (Photo 43A). The bridge suffered no structural damage, although the north faces of the piers showed minor damage due to exposure to the blast. It did, however, receive superficial damage as the concrete railings on both sides were totally damaged and the ornamental posts were dislodged in a direction away from GZ (Photos 43–46 and Fig. 9). It appeared that the girders of the end span had lifted and had been slightly displaced at the abutments. The center span appeared to have been deflected and caused to rebound by the action of the blast which had shaken the entire bridge. Evidence also indicated that the joints of the water main spanning the river between the girders underneath the bridge were slightly damaged.

(11) *Bridge 23* (860 feet from GZ and 2,170 feet from AZ). This plate-girder bridge suffered no structural damage, but received superficial blast damage totally damaging the concrete railings along both sides. The east railing was blown into the river and the west railing was blown toward GZ onto the roadway deck which indicated the instantaneous and rebound effects of the bomb blast (Photos 48 and 49). The cast-iron posts encased in the concrete railings were sheared off at curb elevation. The railings were anchored quite securely at the concrete deck and curbs. This anchorage was provided by the cast-iron posts which were bolted to the outside girder and spaced 5 feet on centers (Fig. 10 and Photos 48 and 49). The ornamental posts at the southeast and southwest corners of the bridge were slightly dislodged. The longitudinal girders received no damage and

there was no indication of displacement of the abutment at the south end of the bridge. The longitudinal girders abutting the south face of Bridge 24 were of cantilever design and showed no indication of deformation (Photos 47 and 70).

(12) *Bridge 24* (1,000 feet from GZ and 2,230 feet from AZ) was located at the intersection of the Ota and Motoyasu Rivers (Photo 70). This bridge of plate-girder design received physical damage of a spectacular and interesting nature but it continued to carry unrestricted highway, pedestrian, and street railway traffic. The longitudinal steel girders suffered no great structural damage although a slight lateral deformation indicated that they had been highly stressed. It was also apparent that the bridge had first been depressed by the blast, and then the girders rebounded upward due to the elastic quality of the steel. Apparently the reflection of the blast wave from the river and the rebounding action raised the roadway and sidewalk slabs from their supporting girders and also moved them laterally at the west end spans of the bridge (Photos 58 and 69) in a direction away from the blast. Although the girders were subjected to large and unusual stresses, the elastic limit of the material was not greatly exceeded. The longitudinal girders, however, did suffer slight deflection, especially those girders under the concrete walk adjacent to the east abutment where they were deflected approximately 2 to 3 inches downward at the center of the span (Photos 62 and 63), and there was a slight lateral deflection (Photos 53, 66, and 67). The girders at the west abutment showed an indication of deformation (Photo 64). The longitudinal girders of the fourth and fifth spans from the east abutment underneath the north walk were slightly deformed laterally and vertically, indicating that stresses were built up in the web-plate and bottom flanges at the piers. The concrete railings were totally damaged. The cast-iron posts encased in the concrete railings were sheared off at curb level, apparently as a result of severe shock effects produced by the blast. The railings were anchored securely to the concrete deck and curbs. This anchorage was provided by the cast-iron posts which were bolted to the outside girder and spaced 6 feet on centers (Photo 61). Other interesting damage features occurred at Bridge 24, such as damaged walks, roadway deck, and granite curbs. These damage features resulted from the shifting of the roadway deck laterally and vertically due to bomb effects. The concrete walk along the north side was pushed approximately 3 feet above its supporting members over the center span (Photo 65). Along the north gutter, the scupper drains were left approximately 2 feet above the roadway because the deck was raised so high off the steel and shifted so far that the scupper pipes hit on girders in falling (Photos 54, 55, 57). Approximately at the bridge center the roadway deck was shifted laterally 15 inches north and raised approximately 14 inches above its original position (Photos 54, 55, 57, and 65). When raised and shifted laterally, the edge of the slab landed on the sidewalk-supporting steel which was at a higher elevation (Figs. 11 and 12). Also at approximately bridge center (opposite Bridge 23) the rails of the south street railway track were raised about 8 inches above their original position. This movement was caused by reflected blast which, however, did not affect Bridge 23 because of the nonrigid connection of the cantilever span abutting the south face of Bridge 24 (Photo 60). The southwest area of Bridge 24 was also affected by blast which raised the concrete walk approximately 20 inches above its original elevation and displaced the granite curb laterally 9½ inches north from its original position. The roadway concrete deck, concrete walk, and granite curb at the northwest corner of the bridge (Photo 59) were also damaged by blast. The shifting of the bridge deck caused a slight lateral deflection in the street railway rails at the east end of the bridge (Photo 68) and also moved the rails laterally 15 inches to the north from their original position at the west end of the bridge (Photo 69). The ornamental stone caps at the corners of Bridge 24, with the exception of the southeast posts, were dislodged by the bomb effects (Fig. 12 and Photo 70). It was learned through interrogation that at the time of the blast approximately 300 Japanese soldiers and many civilians were crossing the bridge and all were hurled into the river.

(13) *Bridge 26* (5,750 feet from GZ and 6,100 feet from AZ) suffered no structural damage. The bomb effects, however, discolored the old paint on the steel members along the south side facing the direction of flash. The north side was unaffected (Photos 72, 73, 74).

(14) *Bridge 27* (4,360 feet from GZ and 4,790 feet from AZ) suffered no structural damage, but the bomb effects discolored the old paint on the steel members along the east side. The members

along the west side were less affected (Photo 75). The bridge was of tied-arch single-span construction.

(15) *Bridge 29* (1,190 feet from GZ and 2,310 feet from AZ), a pin-connected steel truss, was totally damaged by blast. Only stone-faced concrete piers and abutments remained. The blast forces reflected from the water struck the bridge from below and caused an uplift, while the blast striking along the sides caused overturning and failure of the structure which collapsed into the river downstream (Fig. 14). The approximate center height of the trusses was 13 feet above roadway grade. Interrogation indicated that this bridge was approximately 55 years old. It was a highway bridge of very light construction with timber deck and asphalt-wearing surface, and was in fair condition (Photos 77–80).

(16) *Bridge 30A* (1,880 feet from GZ and 2,750 feet from AZ) suffered slight damage by blast. This bridge, known as the Shinobashi Aqueduct, carried a 16-inch water main. It was the nearest steel water crossing to GZ. It was a bow-string truss, built of light, steel angle members, and was supported on concrete piers. The blast caused slight deformation of the truss members. The members adjacent to the west abutment were most severely affected by the blast, and evidence indicated that the deformation of the members was caused by direct blast forces rather than by forces reflected from the water (Photos 85 and 86).

(17) *Bridge 35* (3,190 feet from GZ and 3,750 feet from AZ) was totally damaged by flood (Photos 91 and 92).

(18) *Bridge 37* (3,220 feet from GZ and 3,770 feet from AZ) suffered severe damage by flood which destroyed one pier and two spans adjacent to the west abutment (Photo 94).

(19) *Bridge 44* (5,300 feet from GZ and 5,650 feet from AZ) suffered no damage (Photo 101).

(20) *Bridge 47* (7,450 feet from GZ and 7,700 feet from AZ) suffered no damage (Photo 104).

(21) *Bridge 48* (7,130 feet from GZ and 7,400 feet from AZ) suffered no damage (Photo 105).

(22) *Bridge 50* (6,580 feet from GZ and 6,900 feet from AZ) suffered no structural damage, and the only bomb effect noted was discoloration of the old paint on the steel members along the south side facing the direction of flash. The north side was unaffected (Photo 107).

(23) *Bridge 51* (6,450 feet from GZ and 6,780 feet from AZ) suffered no structural damage. The only indication of bomb effect was discoloration of the old paint on the steel members along the south side facing the direction of flash. The north side was unaffected (Photos 108 and 109).

g. Recapitulation of Damage to Steel Bridges. The 23 steel bridges accommodated 4 types of traffic, with the exception of 3 bridges which carried water crossings.

(1) *Railroad Bridges.* Of the total number of steel bridges, five were railroad bridges carrying a double-track (Bridges 8A, 9, 26, 50, and 51). Bridge 2 carried a single track railroad. These bridges were located from 5,730 feet to 8,480 feet from GZ, Bridge 2 being the most distant. They were built-up, plate-girder sections and suffered no damage.

(2) *Aqueducts.* Three of the total number of steel bridges were used as water crossings. Of these, Bridge 30A was slightly damaged by blast. The others (Bridges 5A and 7A) suffered no damage (Photos 10, 12, and 85). Bridge 30A was the nearest aqueduct to GZ.

(3) *Street Railway Bridges.* There were 4 steel, street-railway bridges of rolled I-beam sections supported by H-column bents with diagonal bracing. These were Bridges 13, 35, 44, and 47, which carried double-track, street-railway traffic. Of these, 1 was completely destroyed by flood. One was initially damaged by blast and later moderately damaged by flood. Two suffered no damage These bridges were located at 4,670 to 7,450 feet from GZ, Bridge 47 being the most distant.

(4) *Highway Bridges.* Ten of the total number of steel bridges studied carried highway traffic. Of the 10, 1 (Bridge 27), a tied-arch, suffered no damage; 1 was a pin-connected steel truss (Bridge 29) which was totally damaged by blast; one was an I-beam girder section with angle stiffeners supported by H-column bents with diagonal bracing (Bridge 20), which suffered only slight superficial damage, and the remaining seven (Bridges 12, 17, 22, 23, 24, 37, and 48) were built-up, plate-girder sections supported on concrete piers. These bridges were located from 260 to 7,600 feet from GZ. Bridge 17 was the most remote highway, plate-girder bridge from GZ. Of these, 4 (Bridges 12, 17, 22, and 23) received superficial damage, and 1 (Bridge 24) received slight structural damage by blast. Bridge 37 was severely damaged by flood. Bridge 48 suffered no damage.

h. Résumé of Fire Damage to Bridges. Fire damaged eight timber bridges and was the cause

of negligible damage to two steel bridges. There was no fire damage to concrete bridges. The eight timber bridges were ignited by fire spread from nearby combustible areas.

(1) Thirteen of the nineteen timber bridges studied (6, 13A, 14, 15, 18, 21, 28, 34, 36, 38, 39, 40, and 43) (Fig. 20) were within the burned-over area. Of the 13, 7 were totally or partly damaged by fire on the day of the attack, and 1 other was partly damaged by fire 3 days later. One end of Bridge 42, a timber structure, was adjacent to the burned-over area, but sustained no fire damage. The 5 timber bridges (1, 11, 32, 46, and 49) which were outside and not adjacent to the burned-over area were not fire damaged.

(2) Timber Bridges 6, 13A, and 43 were damaged initially by blast and later ignited by burning buildings and totally damaged. The other timber bridges which burned had not been blast damaged. Bridges 14 and 34, ignited by burning buildings at both ends were totally damaged. Thirty percent of the east section of Bridge 39 was totaly damaged by fire which spread to it from burning buildings at the east end. Fifty-five percent of the north end of Bridge 40 was totally damaged by fire which spread to it from burning buildings at the north end.

(3) Timber Bridge 38 was neither damaged by blast nor by fire on the day of the attack, but 3 days later 50 percent of the westerly portion of the bridge was totally damaged by fire which was set by embers blown from the still smoldering, burned-over area only 20 feet from its west end.

(4) There was one steel bridge with a wooden deck (Bridge 37) located within the burned-over area. This bridge was undamaged by fire.

(5) There were two street railway Bridges (13 and 44) and two railroad Bridges (9 and 26) of steel construction with wooden ties, within, or adjacent to, the burned-over area. Bridges 13 and 44 sustained no fire damage, whereas Bridge 26 sustained slight flash-burn damage. It was reported that several freight cars burned on Bridge 9 as a result of direct ignition of the cars or their contents by radiated heat from the atomic bomb. Only a few wooden ties were charred and it is possible that they were burned by hot coals dropped previously by locomotives. On Bridges 9 and 26, red paint on the side of steel girders which faced AZ was discolored by radiated heat. Steel bridges were otherwise undamaged by fire.

(6) Concrete bridges sustained absolutely no fire damage.

i. Recapitulation and Summation of Bridge Damage. The damage resulting from many causes and occurring at different times had left a damage analysis problem of considerable complexity at Hiroshima. The cause and extent of damage to the bridge system by the atomic bomb has been segregated from other damage and is summarized in Table 4.

j. Samples and Laboratory Testing of Materials. Samples of two cast-iron, railing-post sections from Bridges 23 and 24 (Sample D) and also paint samples from Bridges 26 and 27 (Sample B) were secured for tests by the Bureau of Standards as follows:

Sample B. Paint samples from Bridges 26 and 27.

(1) Chemical analysis and comparison of samples exposed and unexposed to bomb effects.

(2) Opinion as to agencies causing change, if any, in composition.

Sample D. Two cast-iron, railing-post sections.

(1) Determine tensile, compressive, and shear strengths.

(2) Test for hardness.

(3) Metallurgical analysis.

To date results have been received on Sample D only: "Sample D, *Two Cast-Iron, Railing-Post Sections.* These were identified as being one from Bridge 23, and one from Bridge 24. Specimens for tension, compression, and torsion tests were machined from each section and tested. The results, together with the hardness numbers and chemical composition, follow:

	Bridge 23	Bridge 24
Sample:		
Tensile strength, lb/in [2]	19, 700	22, 700
Compressive strength, lb/in [2]	72, 200	69, 100
Modulus of rupture for torsion, lb/in [2]	26, 500	27, 300
Rockwell indentations number	B80–B90	B75–B85
Chemical composition:		
C, percent	3. 67	3. 71
Mn, percent	. 29	. 22
P, percent	. 17	. 14
S, percent	. 13	. 11
Si, percent	1. 35	1. 26

[2] Pounds per square inch.

ASTM Spec. A48–41 for Gray Iron Castings classifies cast irons by minimum tensile strength. These rails correspond to Class 20, the classifica-

tion of lowest tensile strength. Spec. A48–41 does not provide for compression or torsion strengths, nor for chemical analysis. However, the relationships among the tensile, compressive, and shearing strengths are about the same as in domestic cast irons of this class, and the carbon content is perhaps somewhat higher, and the silicon and manganese contents considerably lower than in most comparable cast irons."

4. Recommendations and Conclusions

a. The Bridge System. The bridge system was satisfactory and adequate to accommodate the service, utility, communication, and transportation systems of Hiroshima. The bridges were conveniently located for efficient travel between islands and mainland. Certain bridges were essential for carrying services and utility lines across the several branches of the Ota River to the many districts of the city. Neglect in planning to provide protection for approaches and ends from flimsy, wooden buildings, rather than any direct physical damage from the atomic bomb, deprived the inhabitants of their use after the attack until relief parties cleared away the debris from fire and blast.

b. Design, Construction Features, Materials and Loading. In general, design, details, and arrangements for timber, concrete, and steel bridges appeared to be below United States standards except for the steel-plate girder bridges for railroads and steel-truss aqueducts which compared favorably with similar structures in the United States. In size and appearance the steel employed in bridge structures was comparable with United States standards; otherwise, the quality of materials appeared to be below that used in the United States for similar structures. Generally the bridges were designed to carry lower loadings than American types.

c. Timber Bridges. The timber bridges (1,450 to 9,800 feet from GZ) generally were of poor construction by American standards. They consisted of many spans of log girders simply supported on multilog-pile bents. Although they were simple in design, low in cost, rapidly and easily erected and repaired, and built of material which was relatively plentiful, they were not sturdy, and fire and blast easily destroyed them. Data indicated that the timber bridges were vulnerable and were less resistant to the atomic bomb than concrete and steel. Based on four bridges, using the average circle of damage method, the mean area of effectiveness of the bomb in causing structural damage by blast to timber pile bridges was 2.4 square miles with a mean effective radius of 4,600 feet.

d. Steel Bridges (260 to 7,600 feet from GZ) were either of built-up, plate-girder sections or standard, rolled-steel sections. Analysis of the data showed the amount of structural damage to steel bridges caused by bomb effects to be relatively small. One bridge (a pin-connected steel truss) was, however, totally damaged by blast. This was a very old bridge about 1,190 feet from GZ and because of its design and age, was an easy victim of the atomic bomb. Although three of the steel bridges were within 1,000 feet of GZ they suffered little or no structural damage. The superficial and minor damage to them was confined largely to the reinforced-concrete decks, sidewalks, railings and ornamental features. There was no evidence which would point to high temperatures as the cause of damage. Several bridges, however, located from 4,360 to 6,580 feet from GZ, were affected by radiant heat to an extent which caused discoloring of the old paint on the steel members facing the direction of the flash. It is concluded that all damage to steel bridges was caused by blast. The mean area of effectiveness of the atomic bomb dropped at Hiroshima was zero for causing structural damage to steel-girder bridges similar to those included in this study. The pin-connected truss bridge totally damaged by blast at 1,190 feet from GZ was judged to be unreliable as a source of data for conclusions on resistance to the bomb.

e. Reinforced-Concrete Bridges (1,930 to 12,200 feet from GZ) showed a striking lack of uniformity in design and in quality of materials. A few whose superstructures were supported on concrete piers appeared more massive than similar structures in the United States. Other concrete bridges, generally supported on concrete bents, were estimated to be below United States standards in design loads. The nearest concrete bridge to GZ (1,930 feet) was Bridge 30 which suffered severe flood damage subsequent to the atomic-bomb attack. Insofar as could be determined by interrogation and post-attack air cover, however, the bridge was open to highway traffic after the attack and was not structurally damaged, although possibly weakened by the atomic bomb. Therefore, the only specific evidence of damage to concrete bridges was the superficial damage from blast to 5 bridges, 4,270 to 6,450 feet from GZ.

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Thus, from an analysis of data, it is concluded that reinforced-concrete bridges were the most effective of all types in withstanding the effects of the atomic bomb. This conclusion is consistent with that of the Building Damage Section of this report which found that "multistory, earthquake-resistant, reinforced-concrete buildings located near the zero point suffered moderate to negligible structural damage." Since the bridges were normally designed to withstand heavier loads than the buildings, and some were earthquake resistant, it is improbable that they would have been structurally damaged even though located nearer GZ. Accordingly it is concluded that for the atomic bomb and height of burst employed at Hiroshima the MAE was zero for causing structural damage to reinforced-concrete girder bridges.

f. Damage Features. It was believed that damage to ornamental features (posts, caps, copings, curbs, and railings), with the possible exception of those bridges within 1,000 feet of GZ, was due largely to inferior design. These particular parts of the bridges were those most severely damaged by blast.

g. Different degrees of blast damage caused to bridge railings and ornamental features appeared in regular concentric areas around GZ. This regular pattern of damage was due to the absence of topographical obstructions which might have protected any particular areas from the blast. At long distances, where the blast was traveling in an almost horizontal direction, damage was inflicted principally on railings facing the flash. Buildings adjacent to bridges, however, provided some shielding for the structures, especially for ornamental features.

h. It was assumed that forces initially originated at AZ were shock forces radiating from that point. This assumption was strengthened by the positions of the railings of Bridge 23, 860 feet from GZ, which fell toward the point of detonation of the bomb. This indicated that these positive forces probably weakened the railings, and negative forces (toward GZ) lasting over a longer period of time completed the collapse. The negative phase, although probably much less powerful than the positive phase, was credited with causing the railings to fall toward GZ.

i. It was further concluded that if the sidewalks, decks, and railings had been strongly anchored to the structural members, the damage would have been greatly decreased. On the other hand, it was recognized that the "floating" decks, if exposed to a more powerful blast weapon, might decrease structural damage to beams and girders by reducing the loads from blast, especially from blast forces reflected onto the underside of the deck. It is evident that if the concrete deck were boxed around the steel members, as in American practice, powerful enough forces would lift the slabs and steel members as a unit with the probability of severe structural damage. It is recommended therefore that deck structures be simply supported on steel members, and designed only to transmit downward loads to the structural beams and girders.

j. Since destruction caused by the atomic bomb was largely associated with fire, comparatively little structural damage was caused to the noncombustible targets such as steel and concrete bridges. No evidence was found of spalled concrete or oxidized steel which would point to fire as the cause of damage.

k. Had the atomic bomb been released closer to GZ, the results of the intense heat and increased pressure would probably have been more destructive to those bridges located within 1,000 feet of GZ.

l. The relatively small amount of structural damage inflicted on the noninflammable bridges studied indicated that in order to destroy such structures higher temperatures and more powerful forces must be developed.

Table 4.—*Recapitulation of bridge damage*

Damage	Timber bridges			Concrete bridges			Steel bridges			Remarks
	Number	Area damage (square feet)	Percent	Number	Area damage (square feet)	Percent	Number	Area damage (square feet)	Percent	
Structure, blast	1	1, 940	20	0	0	0	4	8, 165	20	
Superficial, blast	0	0	0	5	0	0	5	0	0	Broken railings, curbs, copings, and dislodged members.
Blast		1, 740								
Mixed	3		100	0	0	0	0	0	0	
Fire		15, 700								
Do	5	19, 720	66	0	0	0	0	0	0	
Total damaged area.	9	39, 100	68	5	0	0	9	8, 165	8	
SUMMATION										
Total area of damaged bridges.	9	57, 130	48	5	54, 570	42	9	98, 340	47	
Total area of undamaged bridges.*	10	62, 010	52	10	74, 640	58	14	112, 410	53	
Total	19	119, 140	100	15	129, 210	100	23	210, 750	100	
Percent damaged of total area.			33			0			4	

* Included are nine timber, seven concrete, and three steel bridges which were damaged by either flood or typhoon, or both, on 17 Sept. and 5 Oct. 1945, respectively.

PHOTO 1–XII. Bridge 1. Looking west at east side of undamaged bridge over the Enko-Gawa.

PHOTO 2–XII. Bridge 1. Northeast corner of north abutment of undamaged bridge (9,800 feet to GZ, 10,000 feet to AZ).

PHOTO 3-XII. Bridge 2. East elevation of single-track, railroad bridge over the Enko-Gawa (8,480 feet to GZ, 8,740 feet to AZ).

PHOTO 4-XII. Bridge 3. Looking west at flood-damaged, highway bridge over the Enko-Gawa. Water main carried by bents (7,130 feet to GZ, 7,390 feet to AZ).

PHOTO 5–XII. Bridge 3. Reinforcing steel exposed at section of break in deck girder.

PHOTO 6–XII. Bridge 3. Damaged concrete girder.

PHOTO 7–XII. Bridge 3. Steel reinforcement in concrete deck.

PHOTO 8–XII. Bridge 4. North elevation of reinforced-concrete bridge over the Enko-Gawa. Superficial blast damage at northeast corner railing (6,450 feet to GZ, 6,750 feet to AZ).

PHOTO 9–XII. Bridge 4. Southeast corner of east abutment.

PHOTO 10–XII. Bridge 5. Looking north at reinforced-concrete bridge over the Enko-Gawa. Note Bridge 5A (steel truss) north of Bridge 5 (6,210 feet to GZ, 6,510 feet to AZ) undamaged.

PHOTO 11–XII. Bridge 6. Looking south at remains of bridge over Enko-Gawa. Destroyed by blast and fire (5,370 feet to GZ, 5,730 feet to AZ).

PHOTO 12–XII. Bridges 7 and 7A. Looking west between reinforced-concrete, undamaged highway bridge and steel-truss aqueduct over the Kyobashi-Gawa (5,200 feet to GZ, 5,570 feet to AZ).

PHOTO 13–XII. Bridge 8. South elevation of bridge over Kyobashi-Gawa. Superficial blast damage to concrete railings (5,390 feet to GZ, 5,700 feet to AZ).

PHOTO 14–XII. Bridge 8A. Looking north at undamaged, steel, I-beam railroad bridge (5,580 feet to GZ, 5,900 to AZ).

PHOTO 15–XII. Bridge 9. South elevation of undamaged, double-track railroad bridge over the Kyobashi-Gawa.

PHOTO 16–XII. Bridge 9. Paint on south elevation of steel girders discolored by exposure to bomb effects (5,730 feet to GZ, 6,050 feet to AZ).

PHOTO 17–XII. Bridge 9. Paint on north elevation of steel girders unaffected by bomb.

PHOTO 18–XII. Bridge 10. East elevation of bridge over Kyobashi-Gawa showing flood damage (6,950 feet to GZ, 7,250 feet to AZ).

PHOTO 19–XII. Bridge 11. Looking southwest at corner of north abutment (7,960 feet to GZ, 8,200 feet to AZ).

PHOTO 20–XII. Bridge 11. Cable-tied vertical member of west suspension cable.

PHOTO 21–XII. Bridge 11. Looking west at east suspension cables of undamaged bridge over the Kyobashi-Gawa (7,960 feet to GZ, 8,200 feet to AZ).

PHOTO 22–XII. Bridge 11. Underside of deck structure.

PHOTO 23–XII. Bridge. Cable-tied vertical member of west suspension cable.

PHOTO 24–XII. Bridge 12. South elevation of bridge over Kyobashi-Gawa (4,700 feet to GZ, 5,100 feet to AZ).

PHOTO 25–XII. Bridge 12. Ornamental stone post at southwest corner dislodged by blast (4,700 feet to GZ, 5,100 feet to AZ).

PHOTO 26–XII. Bridge 12. Ornamental stone post at southeast corner dislodged by blast (4,700 feet to GZ, 5,100 feet to AZ).

PHOTO 27–XII. Bridge 13. Timber cribbing under trolley tracks at fourth span from east abutment of blast-and flood-damaged bridge over the Kyobashi-Gawa (4,670 feet to GZ, 5,080 feet to AZ).

PHOTO 28–XII. Bridge 13. Looking west at cribbing under trolley tracks at fifth span from east abutment.

PHOTO 29–XII. Bridge 13. South elevation of trolley bridge.

PHOTO 30–XII. Bridge 13. Flood and blast damage (4,670 feet to GZ, 5,080 feet to AZ) north elevation.

PHOTO 31–XII. Bridge 13–A. Looking east at totally damaged timber bridge by blast and fire over the Kyobashi-Gawa.

PHOTO 32–XII. Bridge 13–A. Totally damaged by blast and fire (4,670 feet to GZ, 5,080 feet to AZ.)

PHOTO 33–XII. Bridge 14. West abutment of bridge over the Kyobashi-Gawa, totally damaged by fire (4,760 feet to GZ, 5,170 feet to AZ).

PHOTO 34–XII. Bridge 15. Looking south at undamaged bridge over the Kyobashi-Gawa (5,580 feet to GZ, 5,900 feet to AZ).

PHOTO 35–XII. Bridge 16. North elevation of undamaged, reinforced-concrete, highway bridge over the Kyobashi-Gawa (5,750 feet to GZ, 6,100 feet to AZ).

PHOTO 36–XII. Bridge 17. Looking south at street railway and highway plate-girder bridge over the Kyobashi-Gawa. Superficial blast damage to railings (7,600 feet to GZ, 8,870 feet to AZ).

PHOTO 37–XII. Bridge 18. Undamaged highway bridge over the Motoyasu-Gawa (6,000 feet to GZ, 6,300 feet to AZ).

PHOTO 38–XII. Bridge 19. North elevation of highway bridge over the Motoyasu-Gawa. Ornamental stone posts dislodged by blast (4,270 feet to GZ, 4,720 feet to AZ).

PHOTO 38A–XII. Pre-attack panoramic view of Hiroshima looking north, showing Bridges 19 and 20 in upper right and 31 in upper left.

PHOTO 39–XII. Bridge 20. Looking south at slight blast damage to northwest area of bridge over the Motoyasu–Gawa.

PHOTO 40–XII. Bridge 20. South elevation. Debris deposited against bents by flood (2,900 feet to GZ, 3,450 feet to AZ).

PHOTO 41-XII. Bridge 20. Blast damage to north railing. Note flash burn on asphalt surface of bridge deck (2,900 feet to GZ, 3,450 feet to AZ).

PHOTO 42 XII. Bridge 21. Southwest part of bridge over the Motoyasu-Gawa totally damaged by blast and flood (1,450 feet to GZ, 2,460 feet to AZ).

PHOTO 43–XII. Bridge 22. Pre-attack Japanese photo showing south elevation. Nearest bridge to GZ, 260 feet.

PHOTO 43A–XII. Bridge 22. Superficial blast damage to bridge over the Motoyasu-Gawa (260 feet to GZ, 2,020 feet to AZ).

PHOTO 44–XII. Bridge 22. North elevation. No structural damage.

PHOTO 45–XII. Bridge 22. Stone posts and railing damaged by blast (260 feet to GZ, 2,020 feet to AZ).

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PHOTO 46–XII. Bridge 22. Blast damage and flash-burn to ornamental stone post (260 feet to GZ, 2,020 feet to AZ).

PHOTO 47–XII. Bridge 23. Looking east at west elevation. Note cantilever span adjacent to Bridge 24, over the Ota-Gawa.

PHOTO 48–XII. Bridge 23. Cast-iron post sections and concrete railing sheared off east curb by blast (860 feet to GZ, 2,170 feet to AZ).

PHOTO 19-XII. Bridge 23. Cast-iron post sections and concrete railing along west curb damaged by blast (860 feet to GZ, 2,170 feet to AZ).

PHOTO 50–XII. Bridge 24. North elevation of bridge over Ota-Gawa. Concrete walk and railing damaged by blast.

PHOTO 51–XII. Bridge 24. Southeast part of bridge over Ota-Gawa. Railing damaged by blast (1,000 feet to GZ, 2,230 feet to AZ).

PHOTO 52 XII. Bridge 24. Blast damage to southwest area. Concrete walk raised 20 inches above original road grade. Granite curb moved 9½ inches north from original position (1,000 feet to GZ, 2,230 feet to AZ).

PHOTO 53-XII. Bridge 24. North elevation adjacent to east abutment. No structural damage to steel-plate girders.

PHOTO 54–XII. Bridge 24. Portion of north granite curb and walk. Drain scupper west of Bridge 23, elevated 20 inches above road grade by blast effects.

PHOTO 55–XII. Bridge 24. Portion of north granite curb and walk. Drain scupper east of Bridge 23, elevated 24 inches above road grade by blast effects (1,000 feet to GZ, 2,230 feet to AZ).

PHOTO 56–XII. Bridge 24. North concrete walk pushed by blast effects 38 inches above cross-steel members supporting the north walk (1,000 feet to GZ, 2,230 feet to AZ).

PHOTO 57–XII. Bridge 24. Blast effects moved roadway slab laterally 15 inches north and raised it 14 inches above original position. Note pushed-up scupper (1,000 feet to GZ, 2,230 feet to AZ).

PHOTO 58–XII. Bridge 24. Northwest corner of bridge showing blast damage to concrete walk, granite curb and roadway concrete deck.

PHOTO 59–XII. Bridge 24. Northeast corner of bridge showing blast damage to concrete walk and granite curb (1,000 feet to GZ, 2,230 feet to AZ).

PHOTO 60–XII. Bridge 24. Intersection of Bridges 23 and 24. Rails of south railway tracks pushed up 8 inches above original road grade by blast.

PHOTO 61–XII. Bridge 24. Blast-damaged, cast-iron post sections at northwest corner of intersection of Bridges 23 and 24. Post sections 5 feet on centers for concrete railings of Bridge 23, and 6 feet on centers for Bridge 24 (1,000 feet to GZ, 2,230 feet to AZ).

PHOTO 62–XII. Bridge 24. Northeast corner of steel-plate girder. No structural damage by blast.

PHOTO 63–XII. Bridge 24. Underside of steel-plate girders and cross-members of west abutment. No structural damage (1,000 feet to GZ, 2,230 feet to AZ).

PHOTO 64–XII. Bridge 24. Underside of steel-plate girders and cross-members at west abutment. No structural damage.

PHOTO 65-XII. Bridge 24. Secondary framing of exterior girder under north walk at approximate bridge center. No structural damage.

PHOTO 66–XII. Bridge 24. Inside faces of plate girders, fourth span from east abutment under north walk. Deflected slightly by blast (1,000 feet to GZ, 2,230 feet to AZ).

PHOTO 67–XII. Bridge 24. Inside faces of plate girders, fifth span from east abutment under north walk. Deflected slightly by blast (1,000 feet to GZ, 2,230 feet to AZ).

PHOTO 68–XII. Bridge 24. East end of bridge. Slight deflection in trolley rails due to shifting of bridge deck by blast.

PHOTO 69–XII. Bridge 24. West end of bridge. Streetcar rails moved laterally 15 inches to the north when blast effects shifted bridge deck (1,000 feet to GZ, 2,230 feet to AZ).

PHOTO 70–XII. Intersection of Bridge 23 (left) and Bridge 24 (right). All damage from blast effects. Bridge 23 (860 feet to GZ, 2,170 feet to AZ). Bridge 24 (1,000 feet to GZ, 2,230 feet to AZ).

PHOTO 71–XII. Bridge 25. West elevation of bridge over Ota-Gawa. Flood damage and superficial damage to concrete coping by blast (5,200 feet to GZ, 5,570 feet to AZ).

PHOTO 72–XII. Bridge 26. South elevation of undamaged, double-track railroad bridge over Ota-Gawa (5,750 feet to GZ, 6,100 feet to AZ).

PHOTO 73–XII. Bridge 26. Paint on the south elevation of girders discolored by exposure to bomb effects.

PHOTO 74–XII. Bridge 26. Paint on the north elevation of girders unaffected by bomb effects (5,750 feet to GZ, 6,100 feet to AZ).

PHOTO 75–XII. Bridge 27. West elevation of undamaged bridge over the Temma-Gawa. Paint on the members of the east elevation were discolored by exposure to bomb effects. Steel members of west elevation were only slightly discolored (4,360 feet to GZ, 4,790 feet to AZ).

PHOTO 76–XII. Bridge 28. Remains at north abutment of bridge over the Temma-Gawa. Totally damaged by flood (4,430 feet to GZ, 4,840 feet to AZ).

PHOTO 77-XII. Bridge 29. Looking north at remains of bridge over the Ota-Gawa. Totally damaged by blast.

PHOTO 78-XII. Bridge 29. Southwest corner. Totally damaged by blast (1,190 feet to GZ, 2,310 feet to AZ).

PHOTO 79–XII. Bridge 29. East abutment. Bridge totally damaged by blast (1,190 feet to GZ, 2,310 feet to AZ).

PHOTO 80–XII. Bridge 29. Looking east at debris at west abutment (1,190 feet to GZ, 2,310 feet to AZ).

PHOTO 81–XII. Bridge 30. Looking north at flood damage to highway bridge over the Ota-Gawa. (Note Bridge 30–A, aqueduct.)

PHOTO 82–XII. Bridge 30. Fractured roadway deck and longitudinal beams. Note reinforcing steel and construction joint at junction of beams and slab.

PHOTO 83–XII. Bridge 30. Steel reinforcement in fractured concrete girder.

PHOTO 84–XII. Bridge 30. Fractured roadway deck and girder. Note reinforcing steel.

PHOTO 85–XII. Bridge 30–A. North elevation of aqueduct for 16-inch main over the Ota-Gawa. Slightly damaged by blast.

PHOTO 86–XII. Bridge 30–A. Looking northeast at corner of west abutment. Steel truss slightly damaged by blast. Note damaged covering of 16-inch water main (1,880 feet to GZ, 2,750 feet to AZ).

PHOTO 87–XII. Bridge 31. Looking south at flood-damaged, highway bridge over the Ota-Gawa. Sixteen-inch water main carried by bents. Top portion of northwest corner post dislodged by blast (4,570 feet to GZ, 5,000 feet to AZ).

PHOTO 88–XII. Bridge 32. Looking north at flood-damaged highway bridge over the Temma-Gawa (9,400 feet to GZ, 9,600 feet to AZ).

PHOTO 89–XII. Bridge 33. Looking west at flood-damaged bridge over the Temma-Gawa. Sixteen-inch water main carried by bents (5,300 feet to GZ, 5,650 feet to AZ).

PHOTO 90–XII. Bridge 34. Looking west at timber bridge over the Temma-Gawa. Total damage by fire (3,700 feet to GZ, 4,200 feet to AZ).

PHOTO 91–XII. Bridge 35. Looking north at east abutment of bridge over the Temma-Gawa. Totally damaged by flood.

PHOTO 92–XII. Bridge 35. West abutment of trolley bridge. Totally damaged by flood (3,190 feet to GZ, 3,750 feet to AZ).

PHOTO 93–XII. Bridge 36. East and west abutment of bridge over the Temma-Gawa. Totally damaged by flood (3,200 feet to GZ, 3,760 feet to AZ).

PHOTO 94–XII. Bridge 37. Looking north at plate girder, wooden-deck, highway bridge over the Temma-Gawa. Westerly portion severely damaged by flood. Sixteen-inch water line carried by brackets along south side (3,220 feet to GZ, 3,770 feet to AZ).

PHOTO 95–XII. Bridge 38. Looking west at remains of timber bridge over the Temma-Gawa. Severely damaged by fire (west half) and later totally damaged by flood (3,750 feet to GZ, 4,250 feet to AZ).

PHOTO 96–XII. Bridge 39. Looking northwest at remains of timber bridge over the Temma-Gawa. Severely damaged by fire (easterly ⅓) and later totally damaged by flood (3,880 feet to GZ, 4,390 feet to AZ).

PHOTO 97–XII. Bridge 40. Looking west at bridge over the Fukushima-Gawa. Northerly portion severely damaged by fire (5,360 feet to GZ, 5,700 feet to AZ).

PHOTO 98–XII. Bridge 41. Looking west at undamaged concrete bridge over canal connecting the Yamate-Gawa and the Fukushima-Gawa (6,150 feet to GZ, 6,460 feet to AZ).

PHOTO 99–XII. Bridge 42. Looking west at remains of timber bridge over the Fukushima-Gawa Totally damaged by flood (5,100 feet to GZ, 5,490 feet to AZ).

PHOTO 100–XII. Bridge 43. North elevation of newly constructed timber bridge over the Fukushima-Gawa. Old bridge was totally damaged by blast and fire (5,180 feet to GZ, 5,510 feet to AZ).

PHOTO 101–XII. Bridge 44. Southeast part of undamaged, street railway bridge over the Fukushima-Gawa (5,300 feet to GZ, 5,650 feet to AZ).

PHOTO 102–XII. Bridge 45. Looking northwest at the southeast area of the concrete highway bridge over the Fukushima-Gawa. Moderately damaged by flood (7,010 feet to GZ, 7,010 feet to AZ).

PHOTO 103–XII. Bridge 46. Looking west at remains of timber bridge over the Yamate-Gawa. Totally damaged by flood (8,090 feet to GZ, 8,350 feet to AZ).

PHOTO 104–XII. Bridge 47. Looking north at undamaged trolley bridge over the Yamate-Gawa (7,450 feet to GZ, 7,700 feet to AZ).

PHOTO 105–XII. Bridge 48. Looking north at undamaged plate-girder, concrete-deck, highway bridge over the Yamate-Gawa; 12- and 14-inch water mains are carried by steel saddles between girders (7,130 feet to GZ, 7,400 feet to AZ).

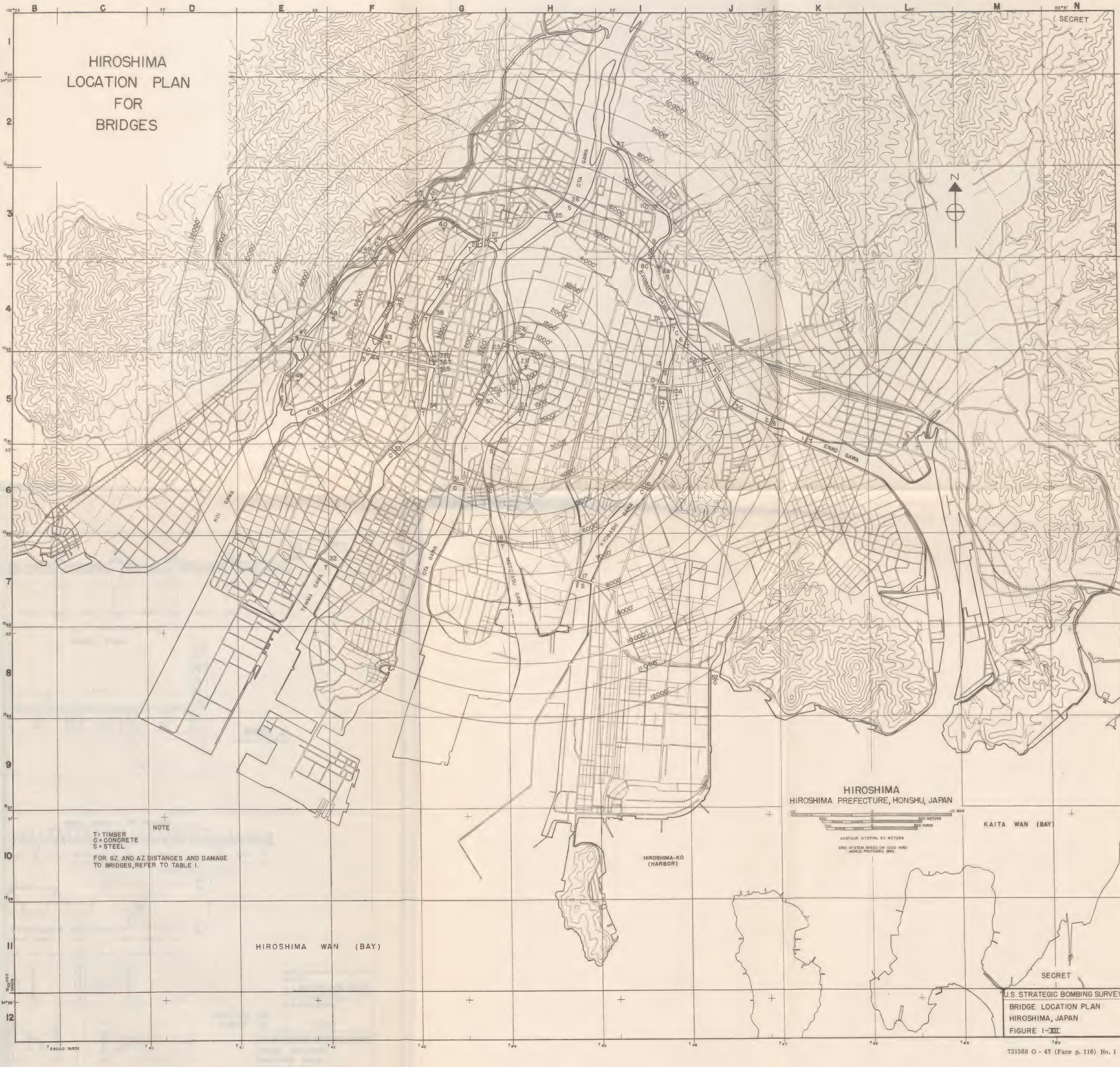
PHOTO 106–XII. Bridge 49. Looking northwest at remains of timber foot bridge over the Yamate-Gawa. Totally damaged by flood (6,380 feet to GZ, 6,650 feet to AZ).

PHOTO 107–XII. Bridge 50. South elevation of undamaged, plate-girder railroad bridge over the Yamate-Gawa. Paint on girders on the south elevation was slightly discolored by exposure to bomb effects. North elevation unaffected (6,580 feet to GZ, 6,900 feet to AZ).

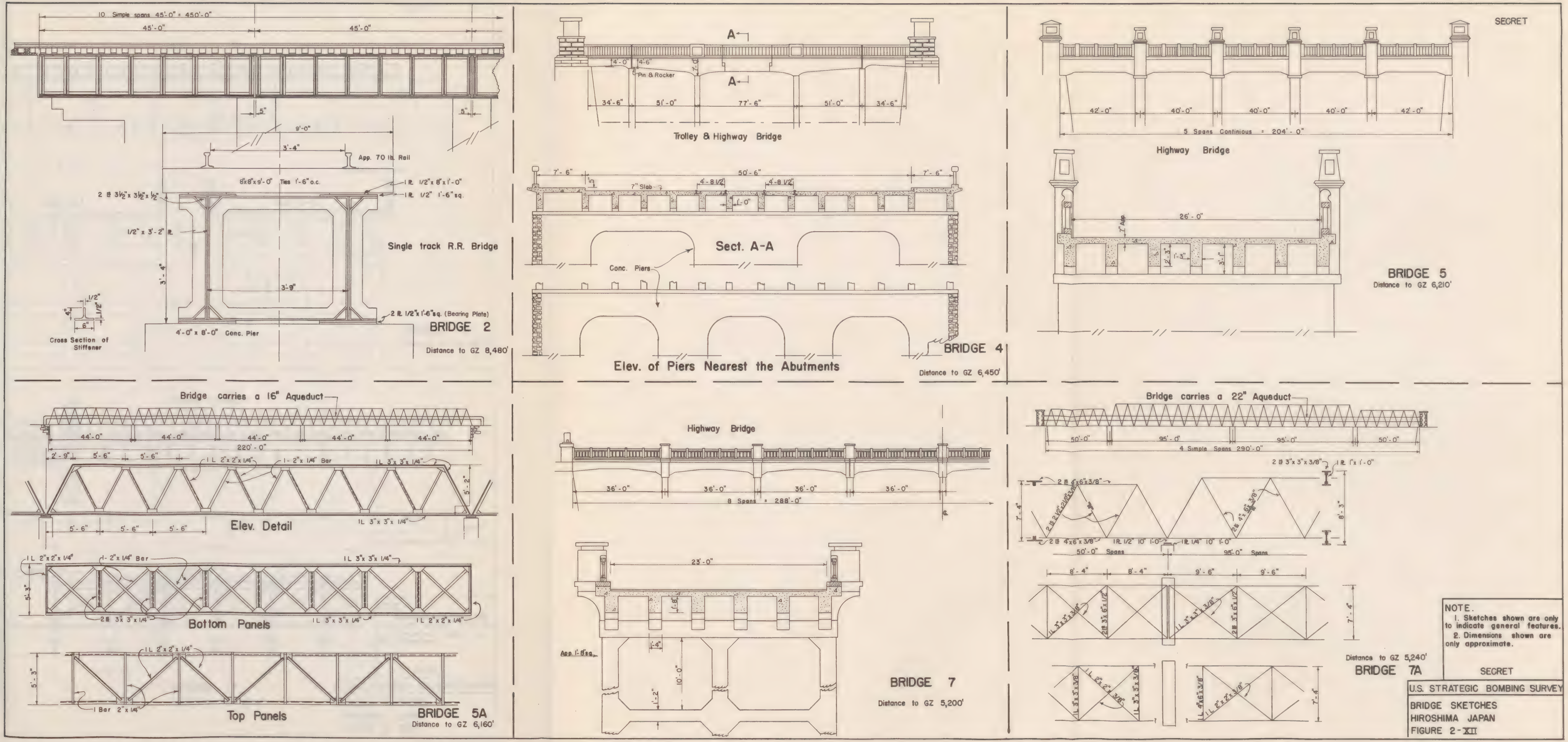
PHOTO 108–XII. Bridge 51. South elevation of undamaged, plate-girder railroad bridge and underpass. Paint on girders on the south elevation was slightly discolored by exposure to bomb effects. North elevation was unaffected (6,450 feet to GZ, 6,780 feet to AZ).

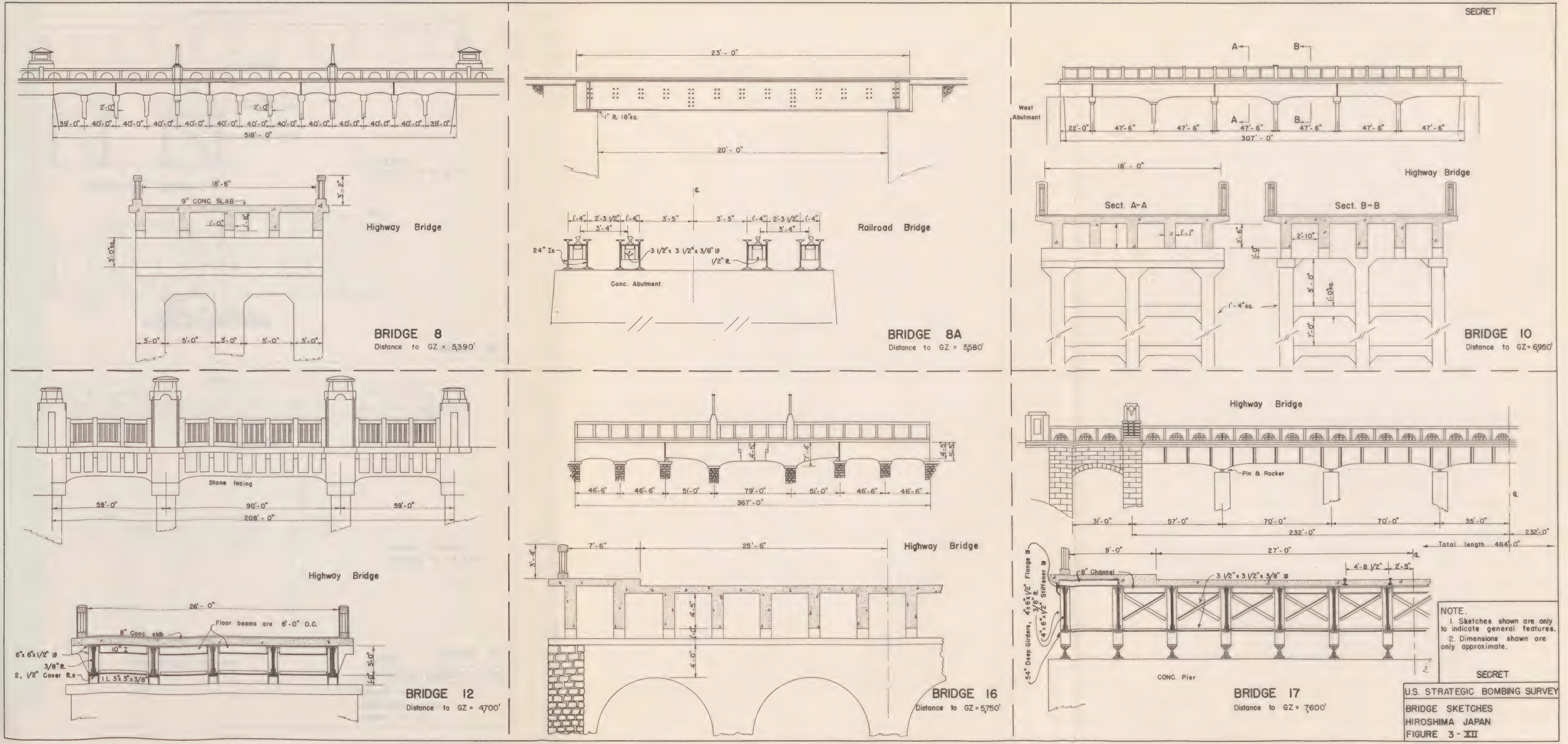
PHOTO 109–XII. Bridge 51. Cast metal sign fastened to the face of the north plate girder, showing Cooper E–40 loading, etc.

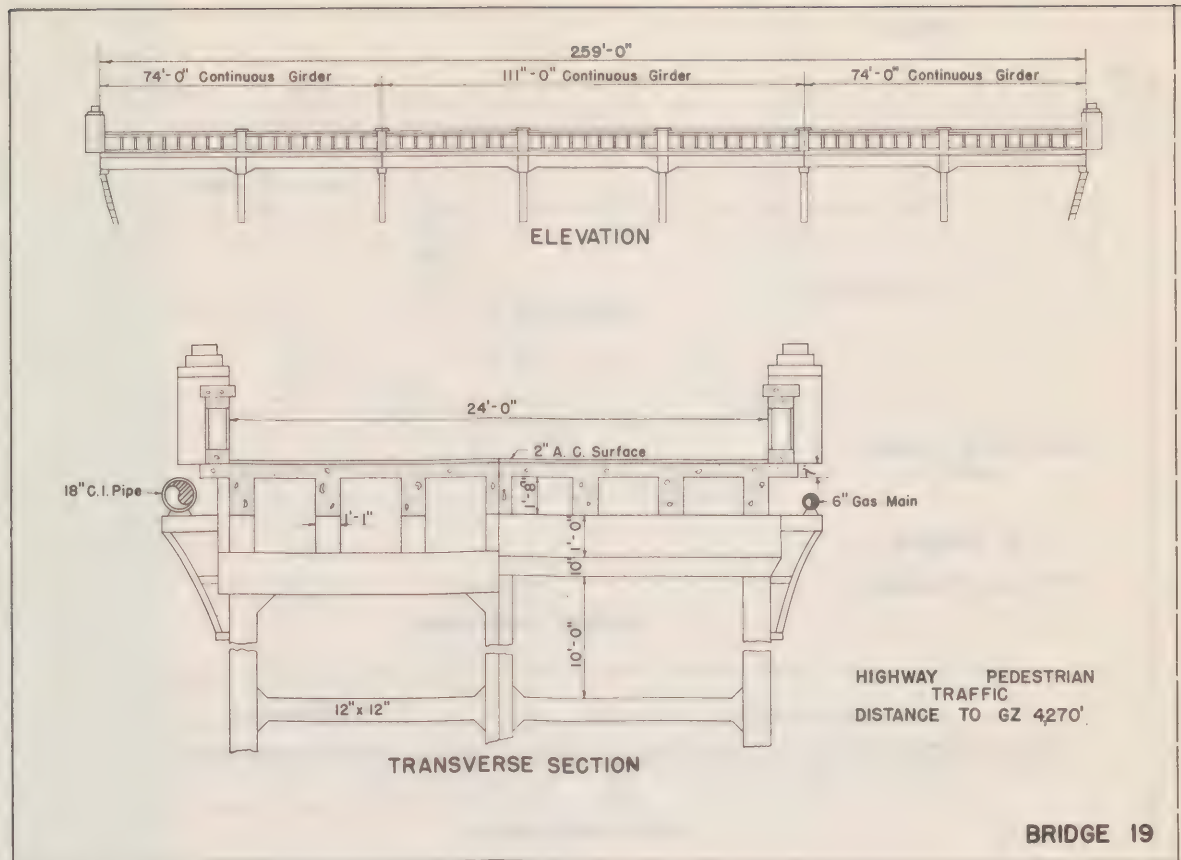
PHOTO 110 XII. Bridge 52. General oblique view showing most remote bridge included in study (12,200 feet to GZ, 12,450 feet to AZ).

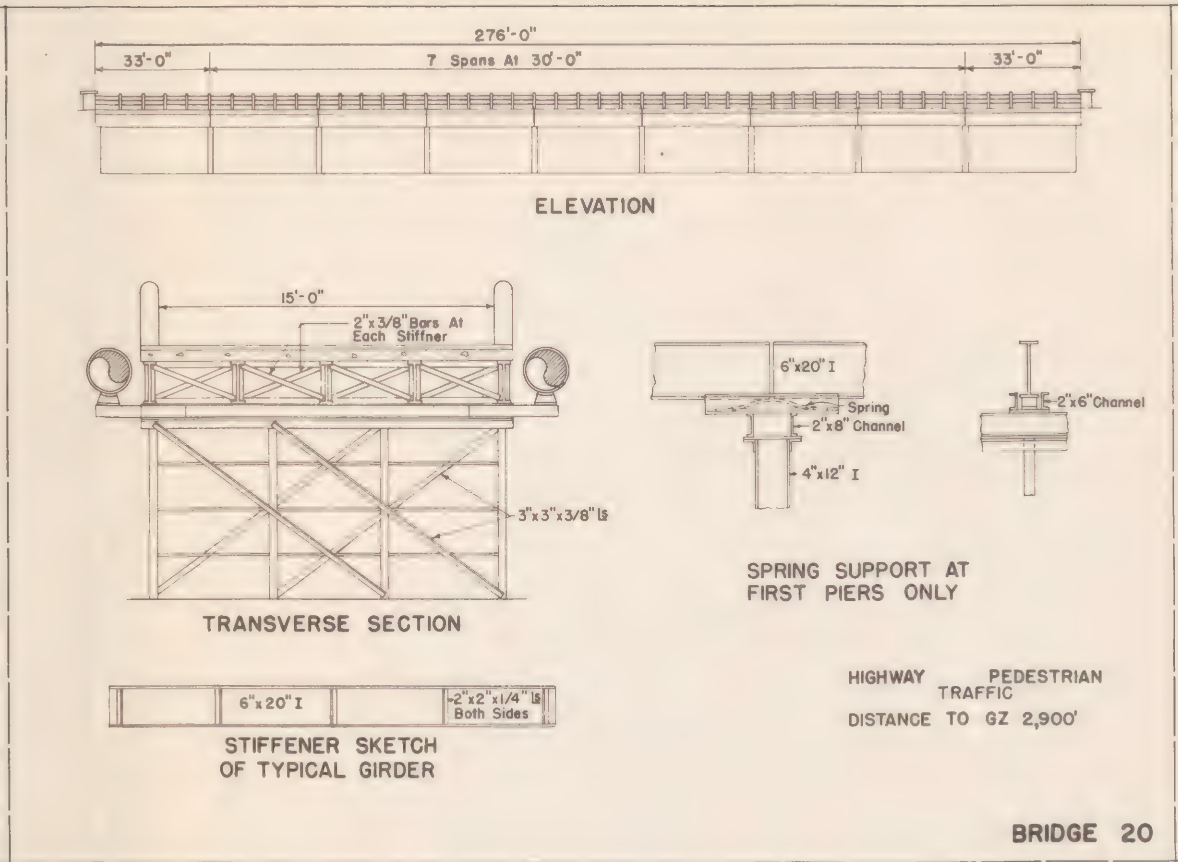


731568 O - 47 (Face p. 116) No. 1


SECRET
10 Simple spans 45'-0" = 450'-0"
45'-0"
45'-0"
5"
5"
9'-0"
3'-4"
App. 70 lb. Rail
6"x8"x9'-0" Ties 1'-6" o.c.
1 PL 1/2"x 8"x 1'-0"
1 PL 1/2" 1'-6" sq.
2 ∠ 3 1/2"x 3 1/2"x 1/2"
1/2" x 3'-2" PL
3'-4"
3'-9"
2 PL 1/2"x 1'-6" sq. (Bearing Plate)
4'-0" x 8'-0" Conc. Pier
Cross Section of Stiffener
Single track R.R. Bridge
BRIDGE 2
Distance to GZ 8,480'
A
A
4'-0"
4'-6"
Pin & Rocker
34'-6"
51'-0"
77'-6"
51'-0"
34'-6"
Trolley & Highway Bridge
7'-6"
50'-6"
7'-6"
7" Slab
4'-8 1/2"
4'-8 1/2"
1'-0"
Sect. A-A
Conc. Piers
Elev. of Piers Nearest the Abutments
BRIDGE 4
Distance to GZ 6,450'
42'-0"
40'-0"
40'-0"
40'-0"
42'-0"
5 Spans Continious = 204'-0"
Highway Bridge
26'-0"
1' App.
2'-3"
1'-3"
3'-1"
BRIDGE 5
Distance to GZ 6,210'
Bridge carries a 16" Aqueduct
44'-0"
44'-0"
44'-0"
44'-0"
44'-0"
220'-0"
2'-9"
5'-6"
5'-6"
1 L 2"x 2"x 1/4"
1 - 2"x 1/4" Bar
1 L 3"x 3"x 1/4"
5'-2"
5'-6"
5'-6"
5'-6"
Elev. Detail
1 L 3"x 3"x 1/4"
1 L 2"x 2"x 1/4"
1 - 2"x 1/4" Bar
1 L 3"x 3"x 1/4"
5'-3"
2 ∠ 3"x 3"x 1/4"
Bottom Panels
1 L 3"x 3"x 1/4"
1 L 2"x 2"x 1/4"
1 L 2"x 2"x 1/4"
5'-3"
1 Bar 2"x 1/4"
Top Panels
BRIDGE 5A
Distance to GZ 6,160'
Highway Bridge
36'-0"
36'-0"
36'-0"
36'-0"
8 Spans = 288'-0"
23'-0"
1'-8"
App. 1'-8" sq.
1'-4"
10'-0"
1'-2"
BRIDGE 7
Distance to GZ 5,200'
Bridge carries a 22" Aqueduct
50'-0"
95'-0"
95'-0"
50'-0"
4 Simple Spans 290'-0"
2 ∠ 3"x 3"x 3/8"
1 PL 1'x 1'-0"
2 ∠ 4"x 6"x 3/8"
7'-4"
8'-3"
2 ∠ 4"x 6"x 3/8"
1 PL 1/2" 10" 1'-0"
1 PL 1/4" 10" 1'-0"
50'-0" Spans
95'-0" Spans
8'-4"
8'-4"
9'-6"
9'-6"
7'-4"
7'-4"
Distance to GZ 5,240'
BRIDGE 7A
NOTE.
1. Sketches shown are only to indicate general features.
2. Dimensions shown are only approximate.
SECRET
U.S. STRATEGIC BOMBING SURVEY
BRIDGE SKETCHES
HIROSHIMA JAPAN
FIGURE 2-XII


SECRET
39'-0"
40'-0"
2'-0"
518'-0"
18'-6"
9" CONC. SLAB
3'-2"
1'-0"
3'-0"sq.
3'-0"
5'-0"
Highway Bridge
BRIDGE 8
Distance to GZ = 5,390'
23'-0"
1" R. 18"sq.
20'-0"
1'-4"
2'-3 1/2"
3'-4"
3'-5"
24" Is
3 1/2"x 3 1/2"x 3/8" L
1/2" R
Conc. Abutment
Railroad Bridge
BRIDGE 8A
Distance to GZ = 5,580'
A
B
West Abutment
22'-0"
47'-6"
307'-0"
18'-0"
Highway Bridge
Sect. A-A
Sect. B-B
1'-1"
2'-6"
2'-10"
1'-0"
5'-0"
1'-0"sq.
1'-4"sq.
7'-0"
BRIDGE 10
Distance to GZ = 6,950'
Stone facing
59'-0"
90'-0"
208'-0"
Highway Bridge
26'-0"
8" Conc. slab
Floor beams are 6'-0" O.C.
10" I
6"x 6"x 1/2" L
3/8" R
2, 1/2" Cover R.s
1 L 3 1/2"x 3"x 3/8"
3'-0"
BRIDGE 12
Distance to GZ = 4,700'
46'-6"
51'-0"
79'-0"
367'-0"
7'-6"
25'-6"
3'-4"
4'-5"
4'-0"
Highway Bridge
BRIDGE 16
Distance to GZ = 5,750'
Highway Bridge
Pin & Rocker
31'-0"
57'-0"
70'-0"
35'-0"
232'-0"
Total length 464'-0"
9'-0"
27'-0"
8" Channel
3 1/2"x 3 1/2"x 3/8" L
4'-8 1/2"
2'-5"
54" Deep Girders, 4"x 6"x 1/2" Flange L, 3/8" R, 4"x 6"x 1/2" Stiffener L
CONC. Pier
BRIDGE 17
Distance to GZ = 7,600'
NOTE.
1. Sketches shown are only to indicate general features.
2. Dimensions shown are only approximate.
SECRET
U.S. STRATEGIC BOMBING SURVEY
BRIDGE SKETCHES
HIROSHIMA JAPAN
FIGURE 3-XII





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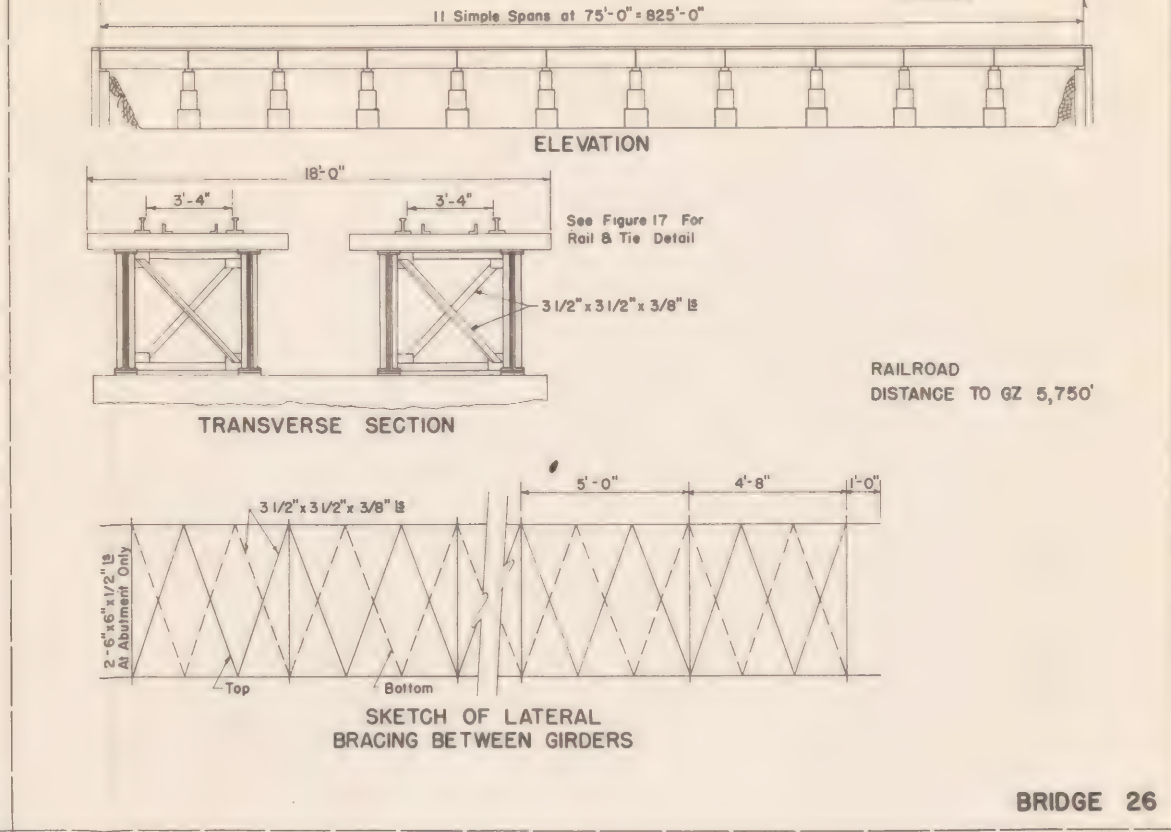

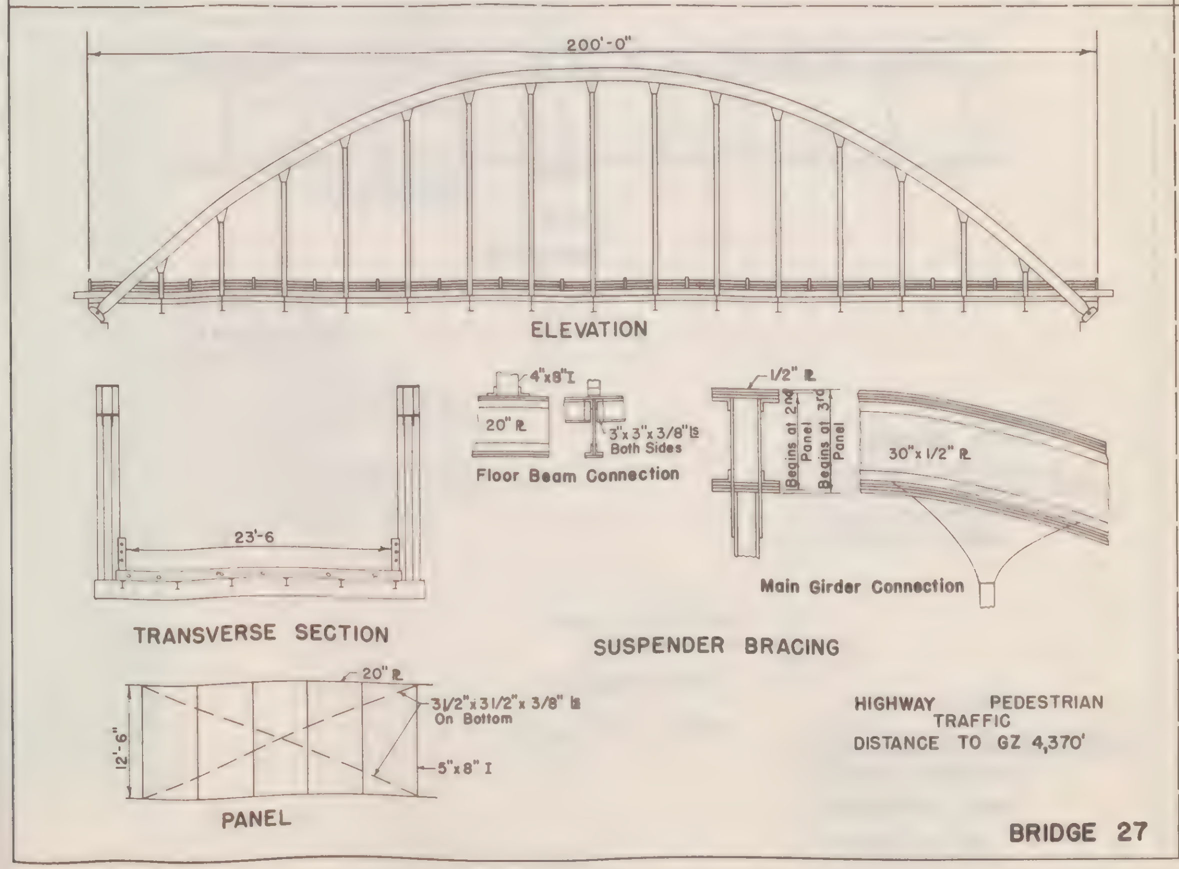

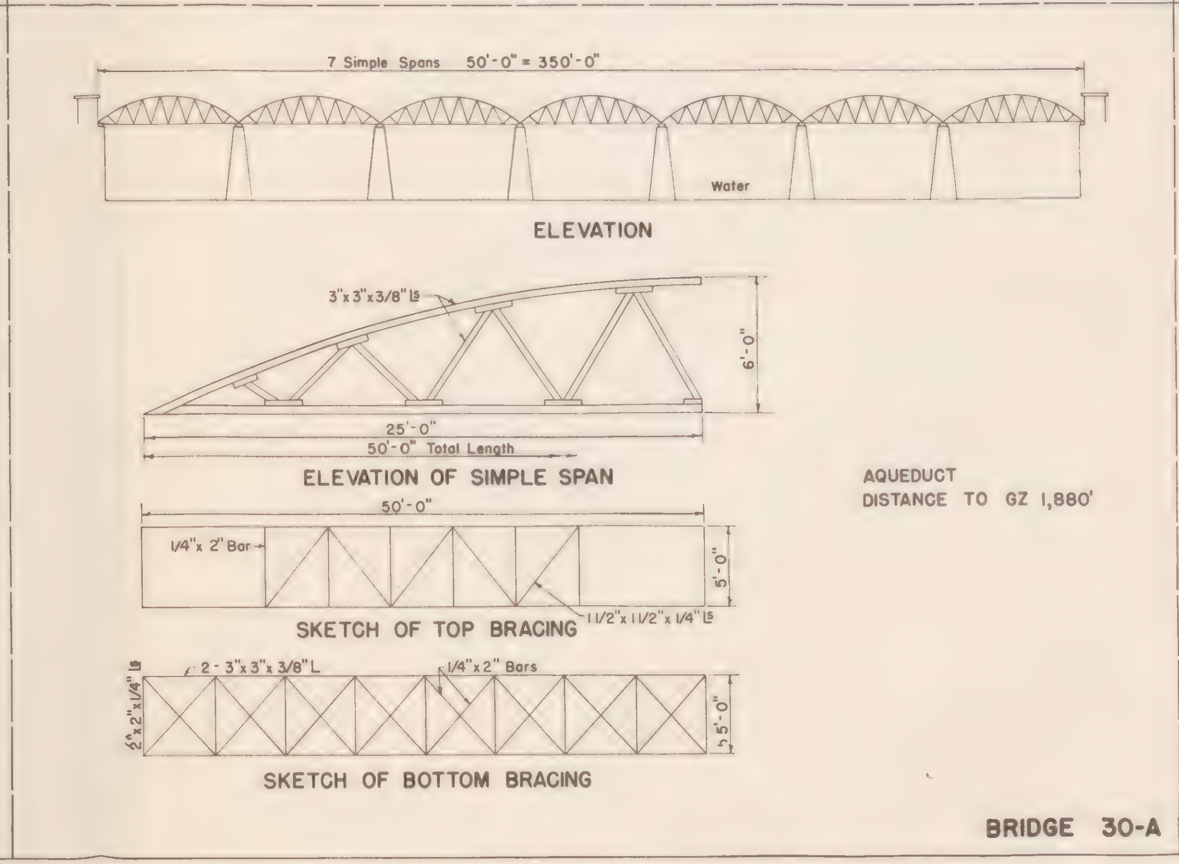

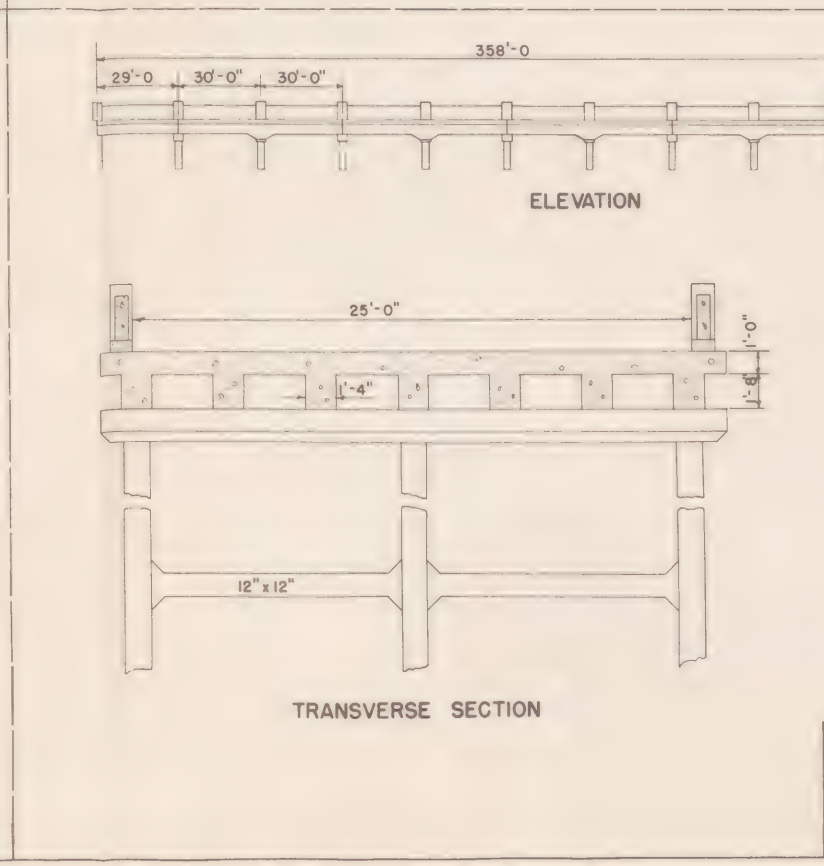

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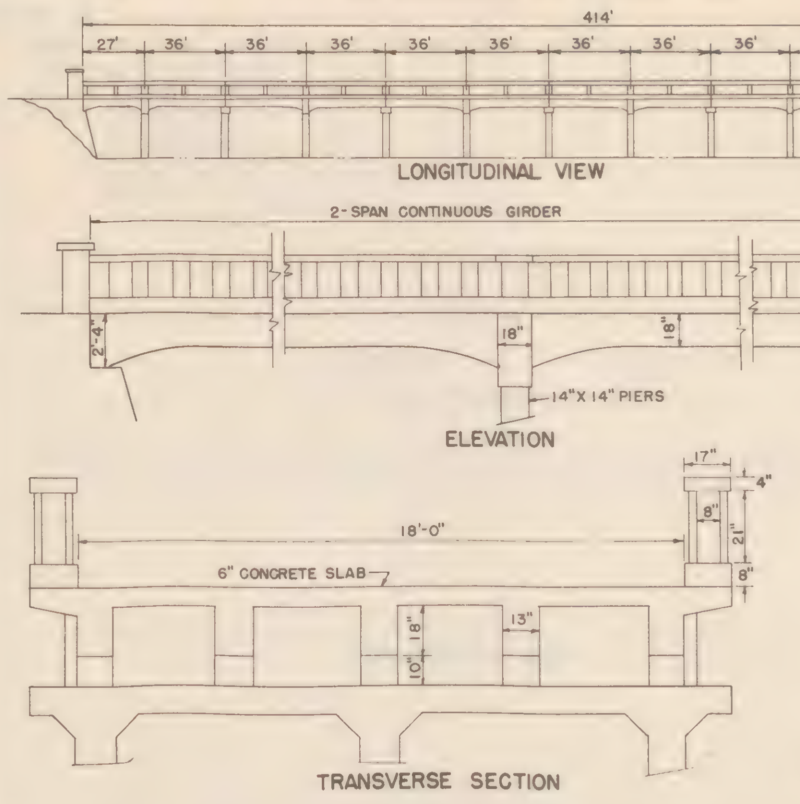
U.S. STRATEGIC BOMBING SURVEY

BRIDGE SKETCHES
HIROSHIMA, JAPAN
FIGURE 4-XII



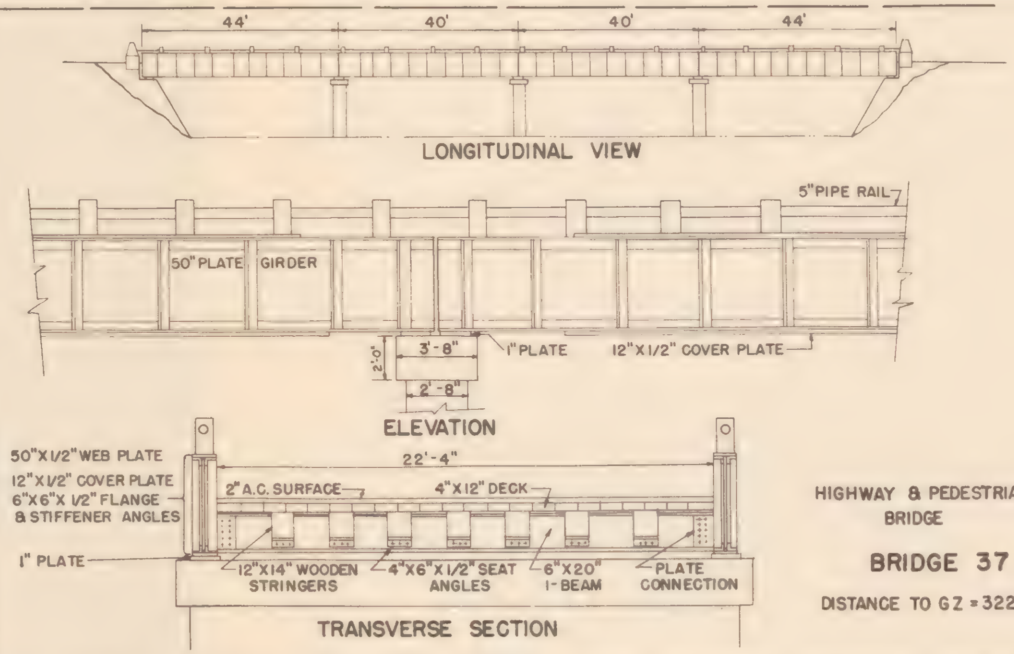
HIGHWAY & PEDESTRIAN BRIDGE

BRIDGE 33

DISTANCE TO G Z =5300'

BRIDGE 35

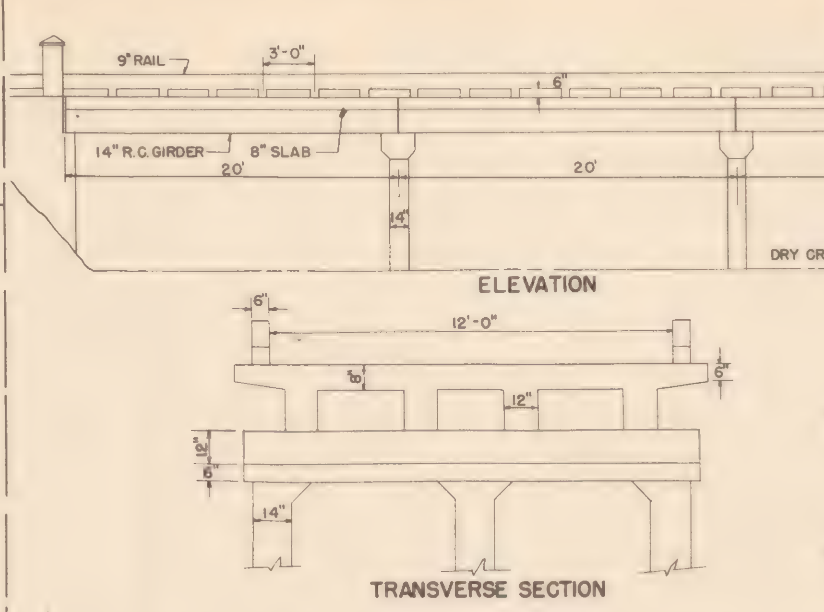
DOUBLE TRACK TROLLEY STRUCTURE SIMILAR TO BRIDGE 13.
8 SPANS AT 33'. LENGTH = 264'.
WIDTH = 16'.
8 7"X24" I-BEAM GIRDERS.
DISTANCE TO G.Z. = 3190'.



HIGHWAY & PEDESTRIAN BRIDGE

BRIDGE 37

DISTANCE TO G Z = 3220'



HIGHWAY & PEDESTRIAN BRIDGE

BRIDGE 41

DISTANCE TO G Z =6150'

BRIDGE 44

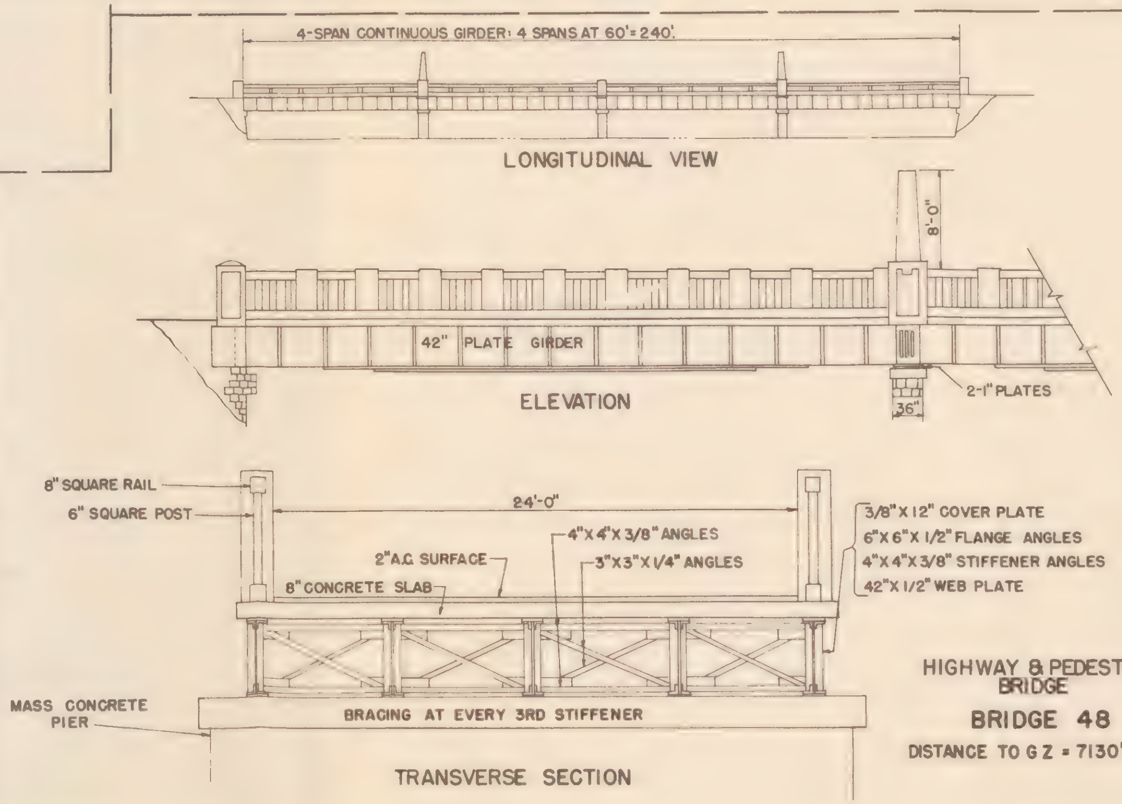
DOUBLE TRACK TROLLEY STRUCTURE SIMILAR TO BRIDGE 13.
14 SPANS AT 34'. LENGTH = 476'.
WIDTH = 16'.
8 7"X24" I-BEAM GIRDERS.
DISTANCE TO G Z = 5300'.

BRIDGE 45

HIGHWAY & PEDESTRIAN TRAFFIC STRUCTURE SIMILAR TO BRIDGE 33.
12 SPANS AT 36'. LENGTH = 432'.
WIDTH = 19'.
5 21"X13" HAUNCHED R.C. GIRDERS. 2-SPAN CONTINUOUS.
DISTANCE TO G Z = 7010'.

BRIDGE 47

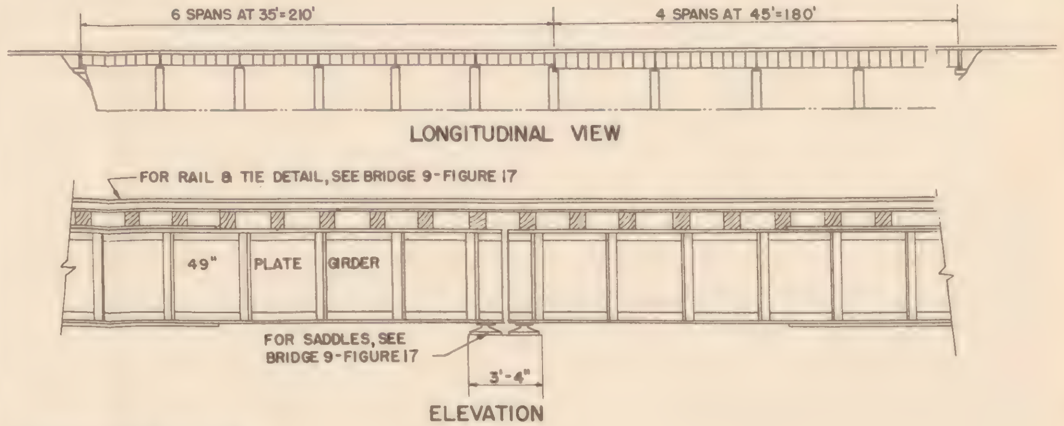
DOUBLE TRACK TROLLEY STRUCTURE SIMILAR TO BRIDGE 13.
10 SPANS AT 34'. LENGTH = 340'.
WIDTH = 16'.
8 7"X24" I-BEAM GIRDERS.
DISTANCE TO G Z = 7450'.
SEE PHOTO 104.



HIGHWAY & PEDESTRIAN BRIDGE

BRIDGE 48

DISTANCE TO G Z = 7130'.



TRANSVERSE SECTION

SIMILAR TO BRIDGE 9-FIGURE 17.
GIRDER: 13"X 1/2" COVER PLATE
4"X6"X 1/2" FLANGE ANGLES
4"X4"X 3/8" STIFFENER ANGLES, EXCEPT 4"X6"X 1/2" ANGLES AT EVERY 4TH STIFFENER
3 1/2"X 3 1/2"X 3/8" LATERAL & SWAY BRACING ANGLES. LATERAL BRACING AT EVERY 4TH STIFFENER ONLY.

DOUBLE TRACK R.R. BRIDGE

BRIDGE 50

DISTANCE TO G Z = 6580'

GENERAL NOTES

1. FOR BRIDGE 13, SEE FIGURE 18.
2. IN MANY CASES, DIMENSIONS & SIZES SHOWN ARE APPROXIMATE, DUE TO STRUCTURAL DAMAGE.

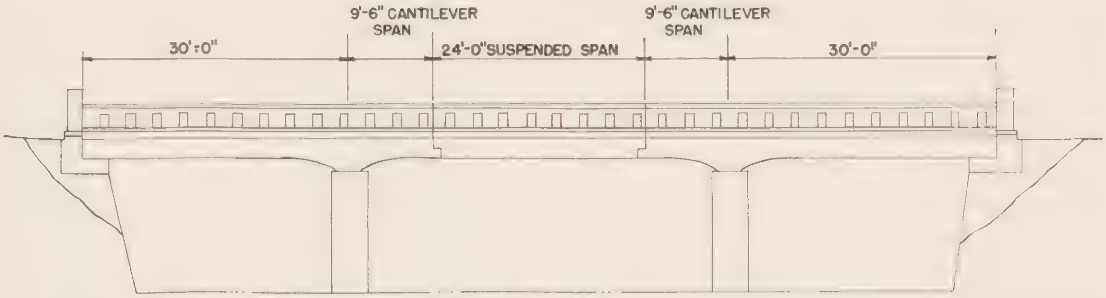
SECRET

U.S. STRATEGIC BOMBING SURVEY
BRIDGE SKETCHES
HIROSHIMA, JAPAN
FIGURE 5-XII

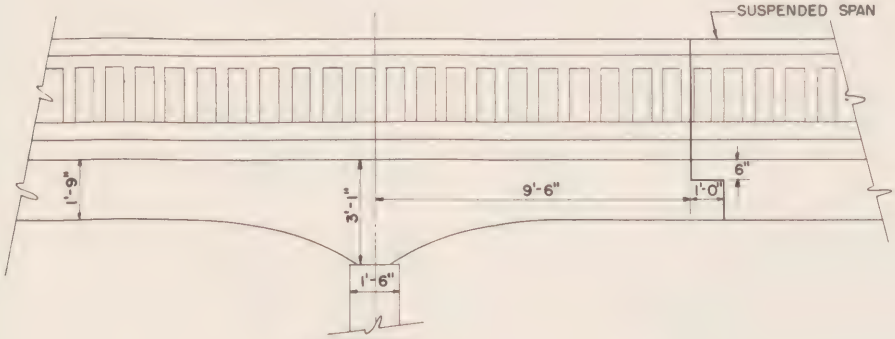
SECRET

BRIDGE 51

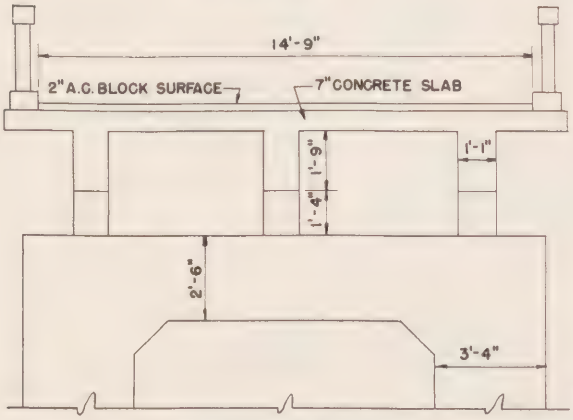
DOUBLE TRACK R.R. STRUCTURE SIMILAR TO BRIDGE 9, FIGURE 17, & BRIDGE 50, FIGURE 5.
2 SPANS AT 33'. LENGTH = 66'.
2 PLATE GIRDERS - 36" & 48" IN DEPTH.
GIRDER: 13" X 1/2" COVER PLATE.
3/8" WEB PLATE.
4" X 4" X 3/8" STIFFENER ANGLES.
BRACING SIMILAR TO BRIDGE 50, FIGURE 5.
DISTANCE TO G Z = 6450'.



LONGITUDINAL VIEW



ELEVATION



TRANSVERSE SECTION

HIGHWAY & PEDESTRIAN TRAFFIC

BRIDGE 52

DISTANCE TO G Z = 12200'

SECRET

U.S. STRATEGIC BOMBING SURVEY
BRIDGE SKETCHES HIROSHIMA, JAPAN FIGURE 6 – XII

DATA SHEETS

GENERAL NOTES

(*a*) *Plan distance* is the distance from the center of bridge to GZ.

(*b*) *Slant distance* is the distance from the center of bridge to AZ.

BRIDGE 1

Coordinates: 5K

Over River: Enko-Gawa.
Distance from "Zero Point": Plan, 9,800; slant, 10,000.
USE: Highway and pedestrian.
DESIGN TYPE: Timber superstructure on pile bents.
MATERIALS USED:
- Longitudinal member: Seven timber beams, 12 by 22 inches per span.
- Decking: Timber, 4 by 10 inches.
- Abutments: Stone masonry.
- Piers: Four piles (12-inch diameter) bent of concrete footings.

SPECIAL FEATURES: Used stapled connections rather than steel bolt.
HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Below United States standards. Generally, the bridges were designed to carry lower loadings than is American practice.
QUALITY OF CONSTRUCTION AND MATERIALS: The design, details and arrangements of the bridge structure were below United States standards. Quality of materials fair.
DAMAGE—EXTENT: None:
CAUSE: None.
REPAIR AND SALVAGE:
EXTENT USABLE:
- Spans: All.
- Piers: All.
- Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:
- Temporary: None.
- Permanent: None.

REMARKS: Bridge being used but timber decking decaying.
PHOTOGRAPHS:

No.	Direction and title
1	Looking west at east side of undamaged bridge over the Enko-Gawa.

PHOTOGRAPHS—Continued

No.	Direction and title
2	Northeast corner of abutment of undamaged bridge.

BRIDGE 2

Coordinates: 5J

Over River: Enko-Gawa.
Distance from "Zero Point": Plan, 8,480; slant, 8,740.
USE: Railroad.
DESIGN TYPE: Plate girder.
MATERIALS USED:
- Longitudinal member: 38 inches in depth. in depth.
- Decking: Ties and rails.
- Abutments: Stones.
- Piers: Concrete.

SPECIAL FEATURES: None.
HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Bridges would carry normal railroad loadings. Comparable with similar structures in United States.
QUALITY OF CONSTRUCTION AND MATERIALS: Comparable with similar structures in United States. Concrete and masonry good.
DAMAGE—EXTENT: None.
CAUSE: None.
REPAIR AND SALVAGE:
EXTENT USABLE:
- Spans: All.
- Piers: All.
- Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:
- Temporary: None.
- Permanent: None.

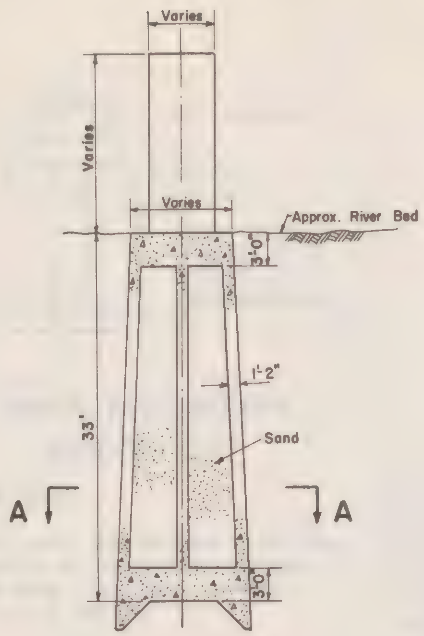
REMARKS: Carrying a single-track railroad.
PHOTOGRAPHS:

No.	Direction and title
3	East elevation of single-track railroad bridge over the Enko-Gawa. Undamaged.

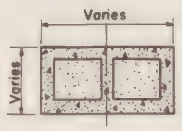
BRIDGE 3

Coordinates: 5J

Over River: Enko-Gawa.
Distance from "Zero Point": Plan, 7,130; slant, 7,390.



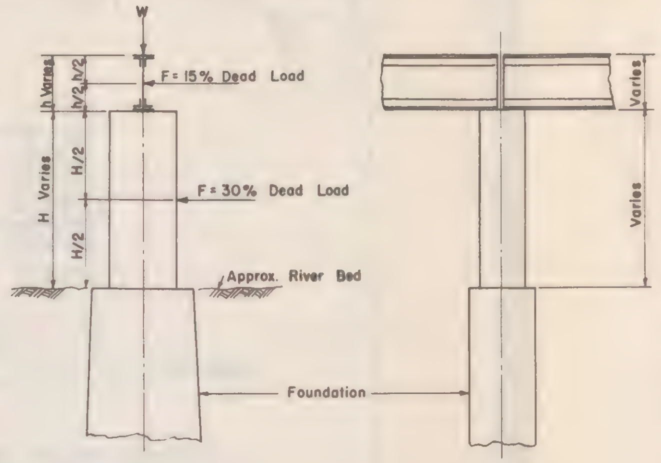
ELEVATION



PLAN A-A

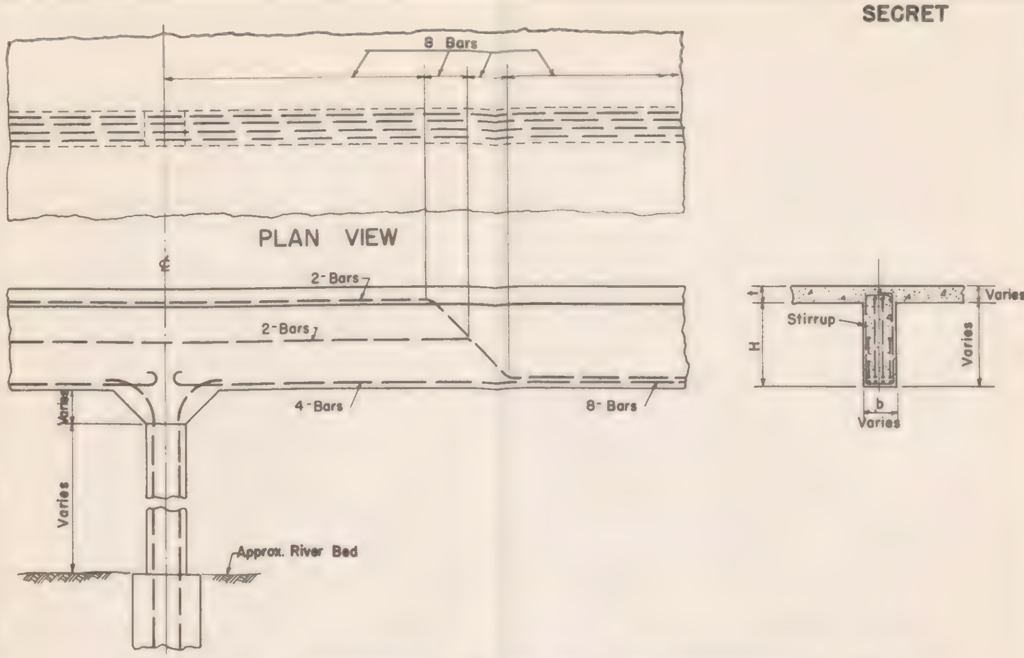
TYPICAL FLOATING PIER

NOTES:
Sand added for additional weight and economy.
Dimensions are only approximate.



TYPICAL EARTHQUAKE DESIGN

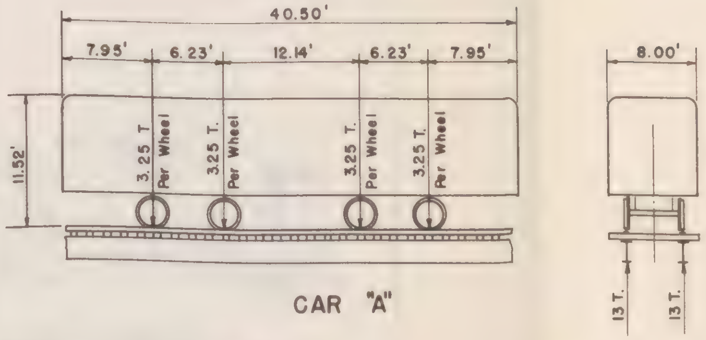
NOTES:
Overturning force for piers = 30% of dead load.
Overturning force for girders = 15 % of dead load.



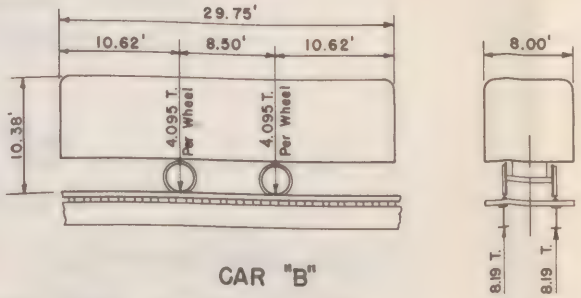
SKETCH SHOWING TYPICAL REINFORCING STEEL

NOTES:
Bars vary in size from 1/4" to 1 3/8"
Deformed bars were not used.
Only smooth round bars used.

TROLLEY CARS
Showing Types "A" and "B"

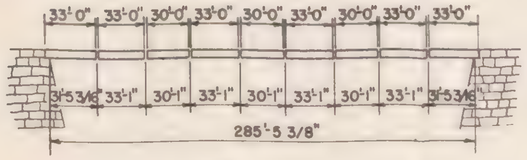


CAR "A"

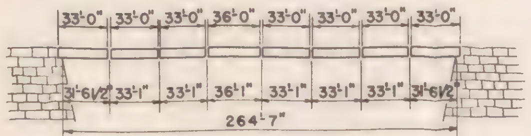


CAR "B"

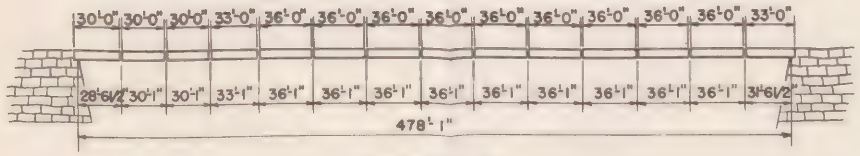
TROLLEY BRIDGES
Showing girder (I-Beams) span lengths and abutments.



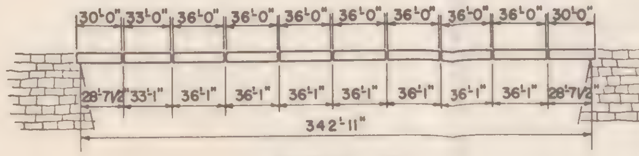
BRIDGE 13



BRIDGE 35



BRIDGE 44



BRIDGE 47

TYPICAL TROLLEY CARS AND BRIDGES

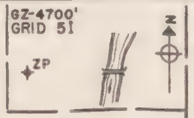
GENERAL NOTES
For schedule of steel material.
All materials of medium steel unless otherwise specified.
All rivets of rivet steel and 3/4" diameter unless otherwise noted.
All rivet holes punched 1/8" less and reamed 1/16" greater diameter than that of rivet.

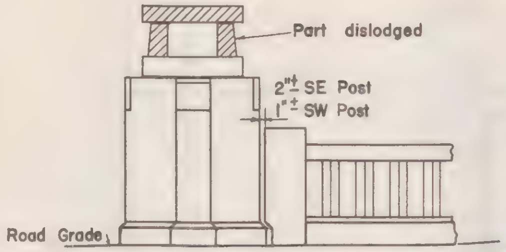
SECRET

U.S. STRATEGIC BOMBING SURVEY

BRIDGES-DESIGN FEATURES
HIROSHIMA, JAPAN
FIGURE 7 – XII

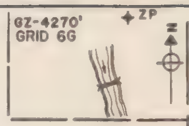
731568 O - 47 (Face p. 118) No. 1

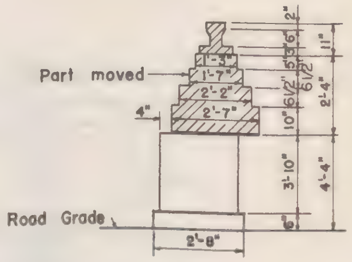




CORNER POST SKETCH
BRIDGE 12

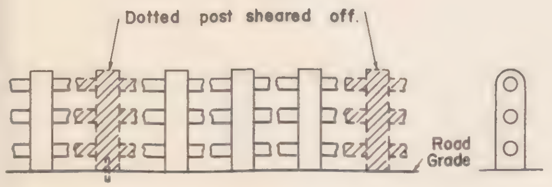
TYPE - Steel Plate Girder
REMARKS :
SE and SW corner posts separated from railing.
Tops of NE and SE corner posts dislodged.
Top of NW corner post partly damaged.
Photos 24, 25 and 26.





CORNER POST SKETCH
BRIDGE 19

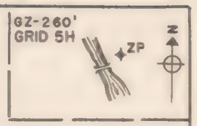
TYPE - Reinforced Concrete
REMARKS :
NE corner post cap blown entirely off.
NW, SE, and SW corner post caps moved 4" to 6" from original position.
Railing 3' above road grade was not disturbed.
Photo 38

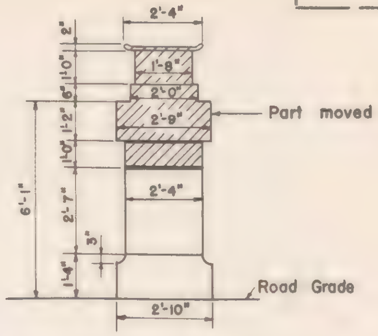


RAILING SKETCH
BRIDGE 20

TYPE - Steel I Beam
REMARKS :
Numerous railing posts connected to slab by cast iron rods sheared off.
Roadway showed shadow marks of north railing.
Tin protective covering of 18" water main on north side slightly effected by blast.
Photos 39, 40, and 41.

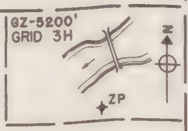
SECRET

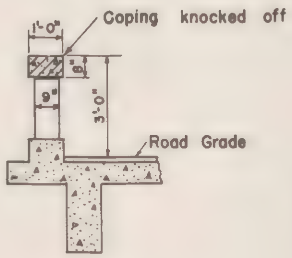




CORNER POST SKETCH
BRIDGE 22

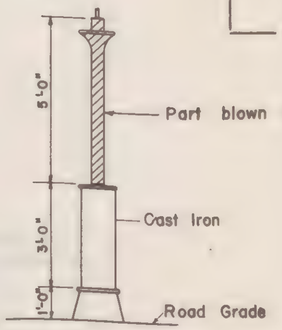
TYPE - Steel Plate Girder
REMARKS :
All stone posts dislodged to some extent at road grade.
NW corner post entirely blown down.
Upper sections of the four center posts were moved 2" to 5" from original position.
Railings entirely destroyed.
Photos 43 to 46 inclusive.





RAILING SKETCH
BRIDGE 25

TYPE - Reinforced Concrete
REMARKS :
NE and SW corner post tops blown off.
SE corner post top displaced 4".
NW corner post top not disturbed.
Concrete railing posts over each pier broken on both south and north railings
Coping blown off both south and north railing
Photo 71

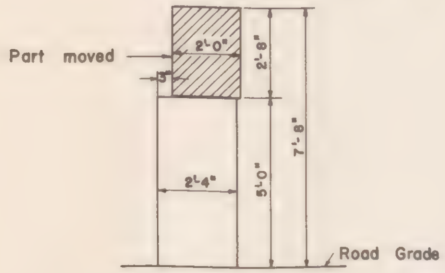


ORNAMENTAL LIGHT POST
BRIDGE 29

TYPE - Pinned Steel Truss
REMARKS :
NE, SE, and SW ornamental cast iron light posts entirely dislodged.
Upper portion of NW corner light post sheared off as shown and blown 50' SW from original position.
Photo 78.

BRIDGE 4

TYPE - Reinforced Concrete
REMARKS:
Portion of concrete railing at NE corner of bridge blown off.
Distance to GZ = 6450'
Photos 8 and 9

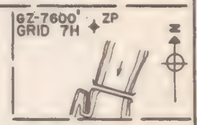


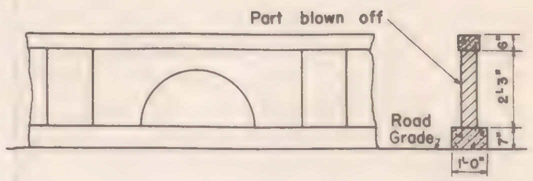
CORNER POST SKETCH
BRIDGE 31

TYPE - Reinforced Concrete
REMARKS :
Top portion of NW corner post dislodged 3" to south.
Other posts not damaged.
Concrete railings not damaged.
Photo 87

BRIDGE 8

TYPE - Reinforced Concrete
REMARKS :
Concrete railings along both elevations of bridge blown off.
Distance to GZ = 5390'
Photo 13





RAILING SKETCH
BRIDGE 17

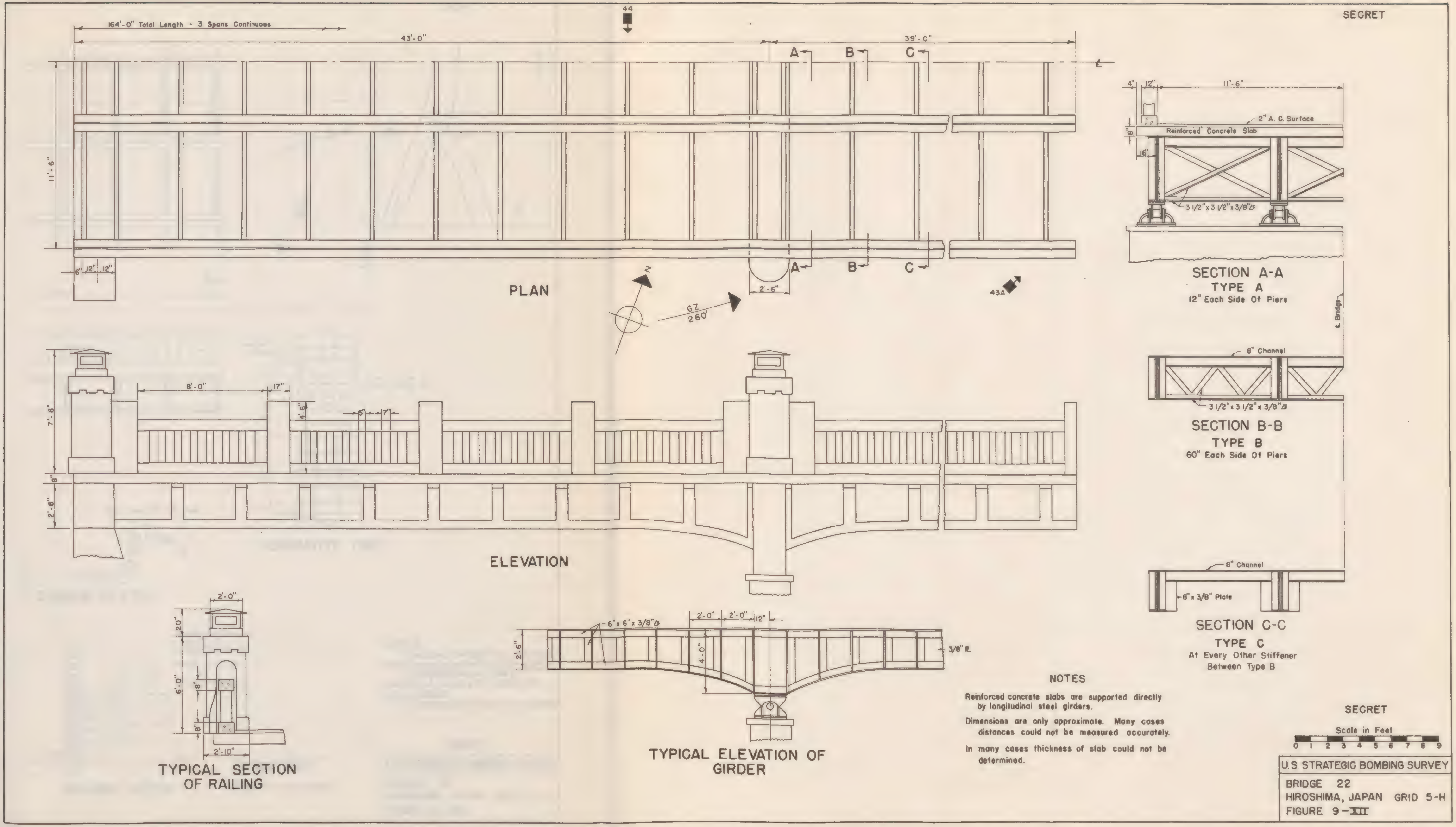
TYPE - Steel Plate Girder
REMARKS :
Stone posts not damaged.
Railings of spans adjacent to east and west abutments were not disturbed.
All other railings blown off.
Photo 36

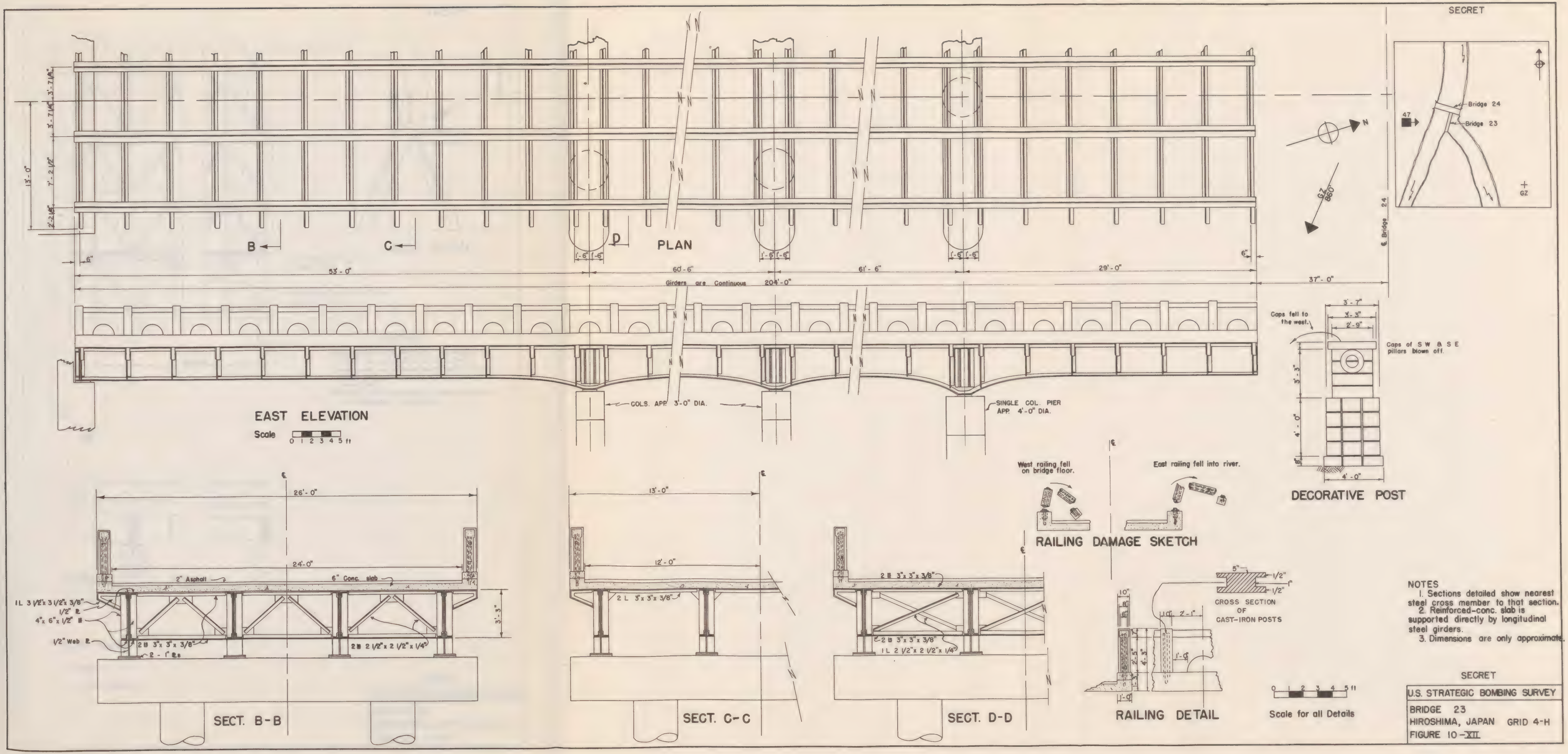
Superficial blast damage.

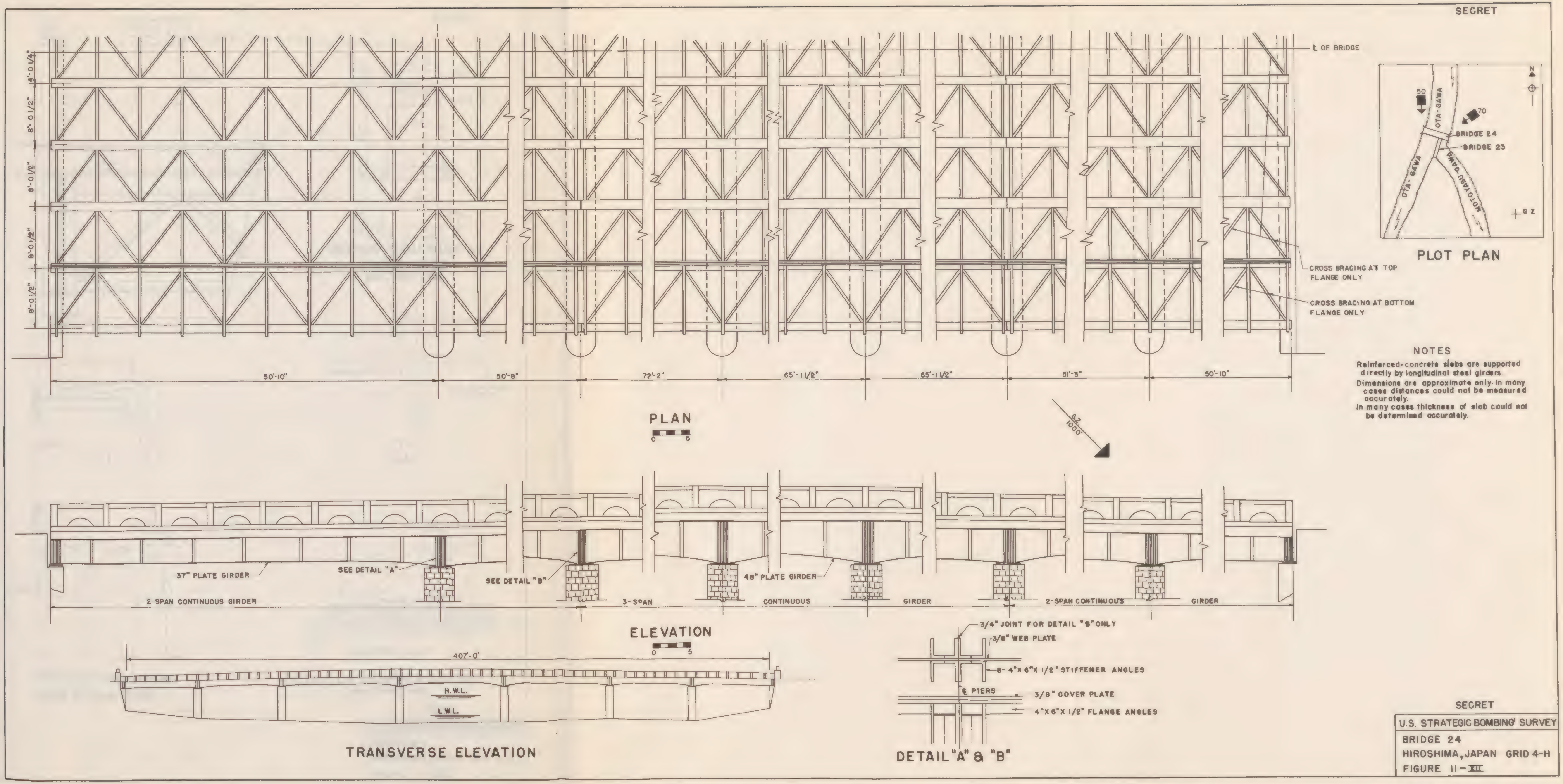
SECRET

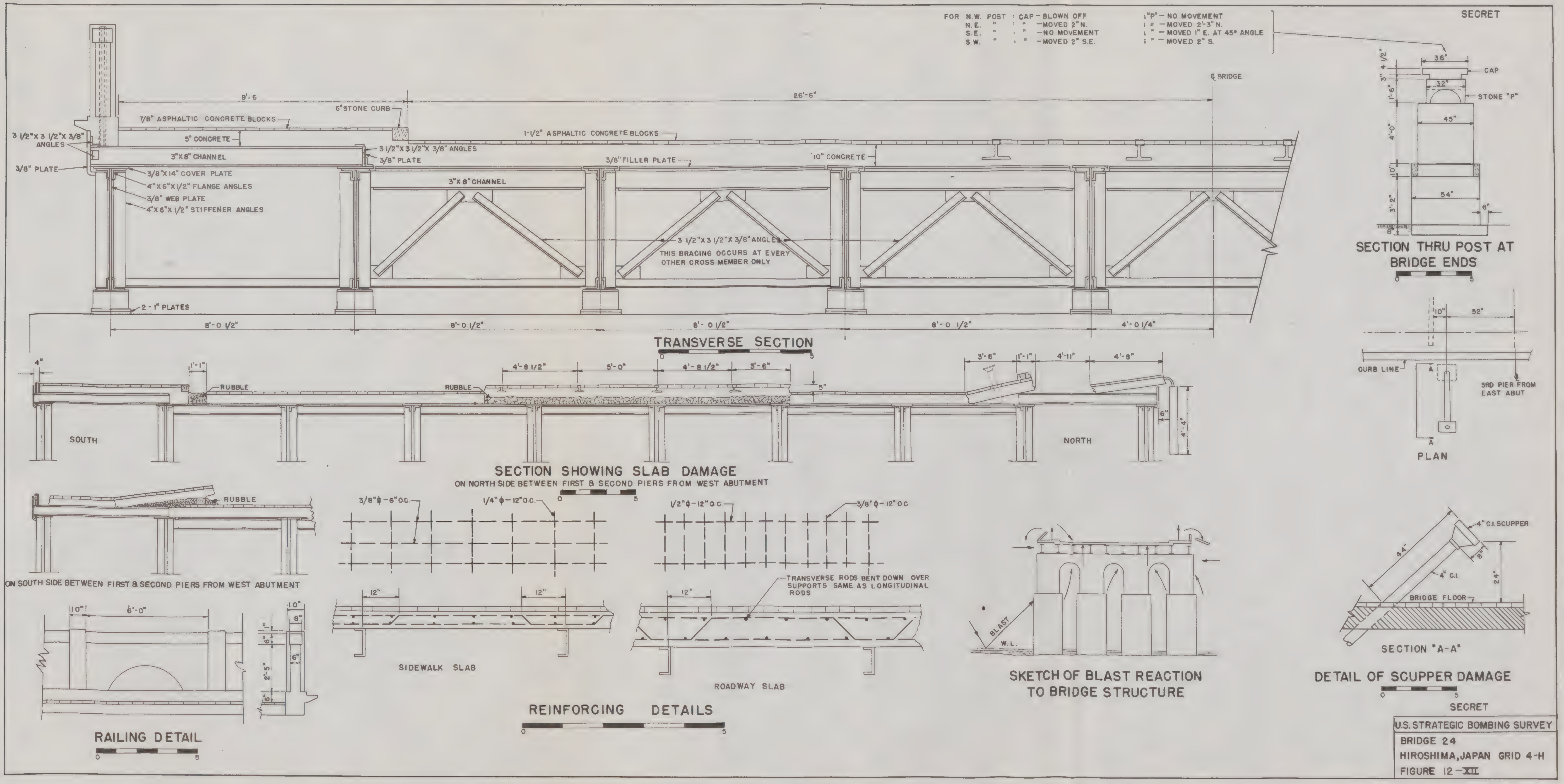
U.S. STRATEGIC BOMBING SURVEY

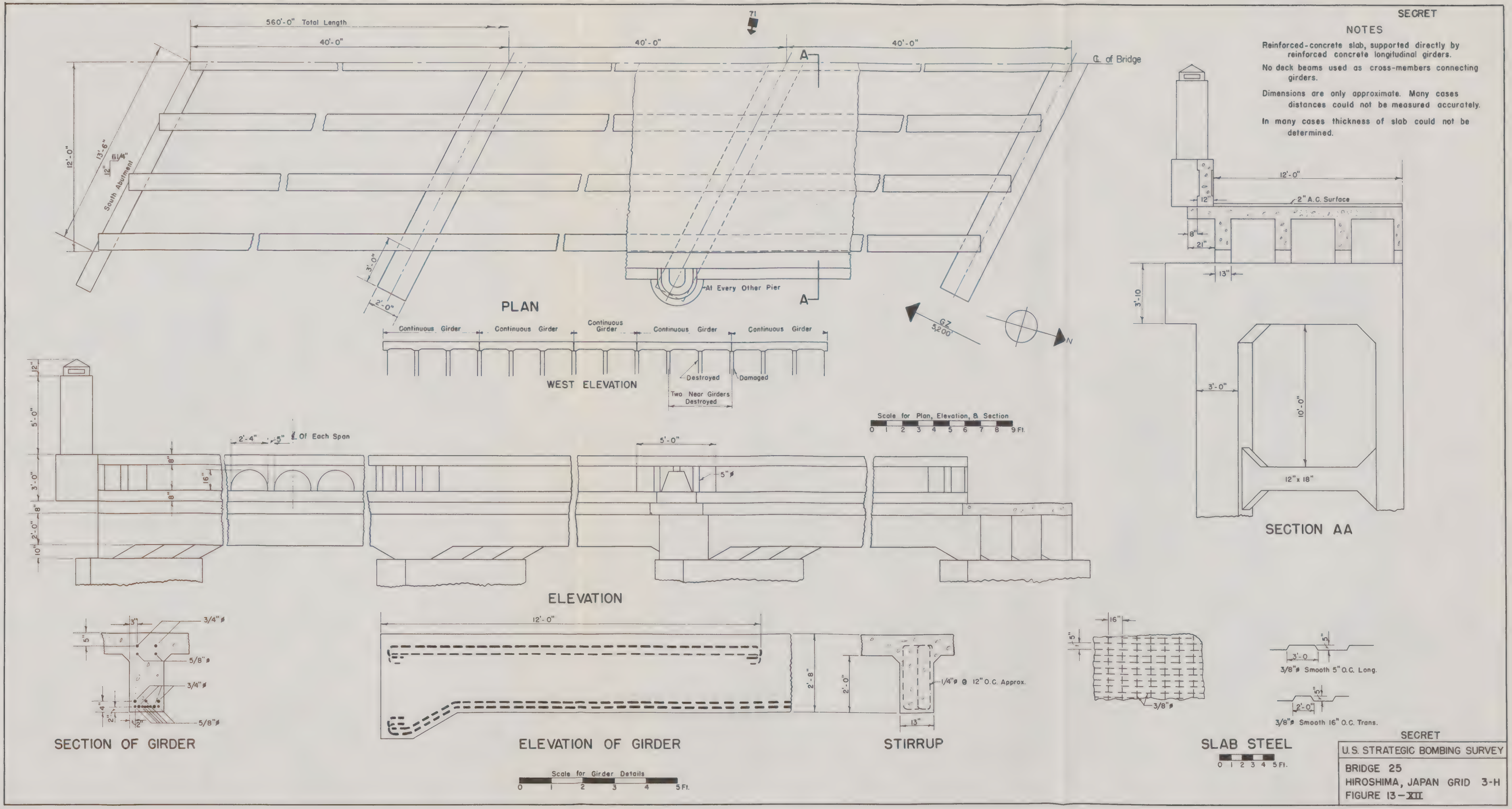
BRIDGES SPECIAL FEATURES
HIROSHIMA, JAPAN
FIGURE 8-XII ORNAMENTAL POSTS AND RAILINGS

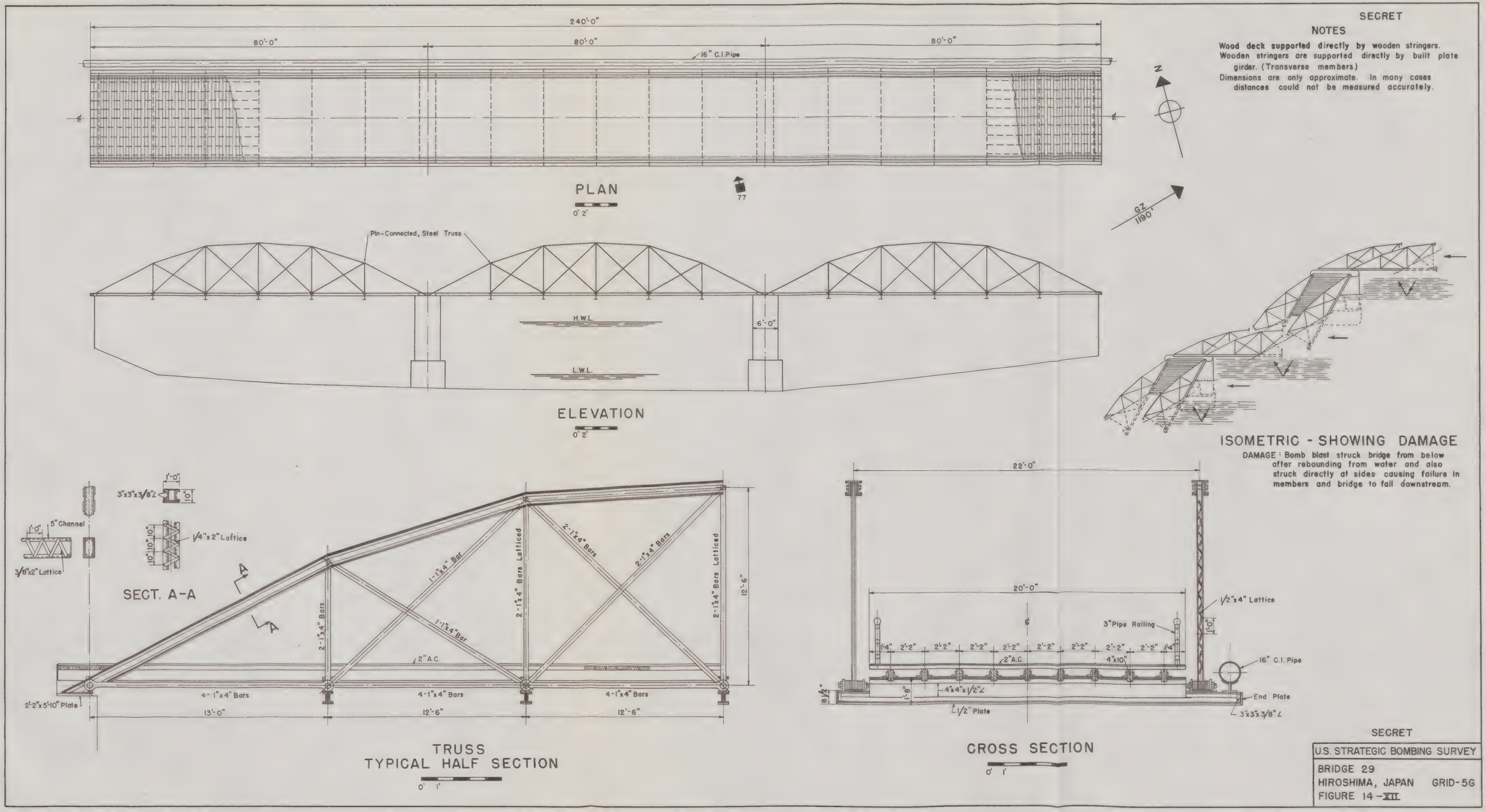

SECRET
164'-0" Total Length - 3 Spans Continuous
43'-0"
39'-0"
11'-6"
PLAN
GZ
260'
43A
44
SECTION A-A
TYPE A
12" Each Side Of Piers
2" A. C. Surface
Reinforced Concrete Slab
3 1/2" x 3 1/2" x 3/8" ∠s
SECTION B-B
TYPE B
60" Each Side Of Piers
8" Channel
SECTION C-C
TYPE C
At Every Other Stiffener Between Type B
6" x 3/8" Plate
℄ Bridge
8'-0"
17"
7'-8"
2'-6"
ELEVATION
TYPICAL SECTION OF RAILING
2'-0"
2'-10"
6'-0"
6" x 6" x 3/8" ∠s
3/8" ℞
4'-0"
TYPICAL ELEVATION OF GIRDER
NOTES
Reinforced concrete slabs are supported directly by longitudinal steel girders.
Dimensions are only approximate. Many cases distances could not be measured accurately.
In many cases thickness of slab could not be determined.
SECRET
Scale in Feet
0 1 2 3 4 5 6 7 8 9
U.S. STRATEGIC BOMBING SURVEY
BRIDGE 22
HIROSHIMA, JAPAN GRID 5-H
FIGURE 9-XII

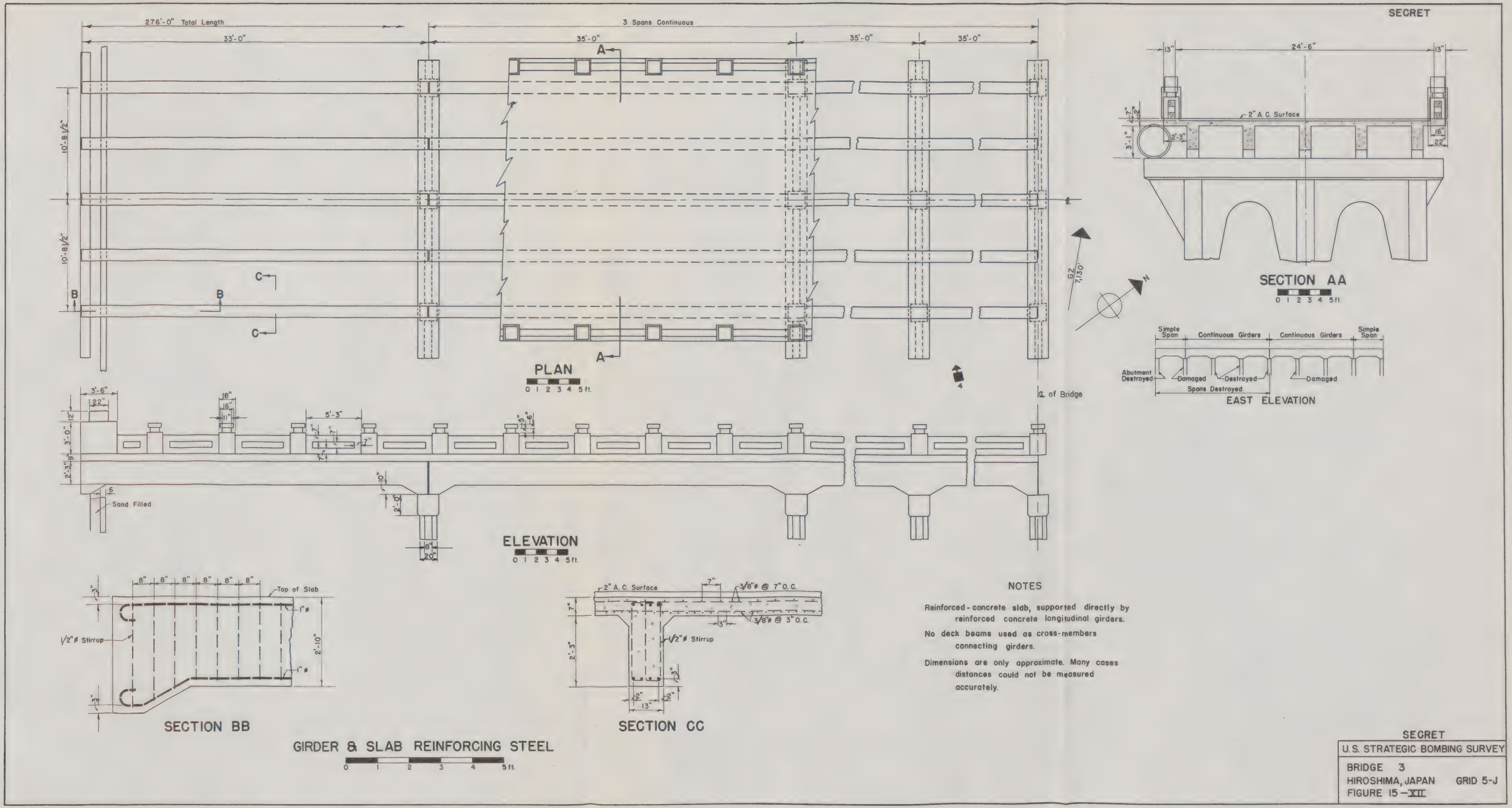

SECRET
PLAN
B
C
D
53'-0"
60'-6"
61'-6"
29'-0"
Girders are Continuous 204'-0"
37'-0"
Bridge 24
Bridge 23
N
GZ 860'
℄ Bridge 24
EAST ELEVATION
Scale
COLS. APP. 3'-0" DIA.
SINGLE COL. PIER APP. 4'-0" DIA.
Caps fell to the west.
Caps of S W & S E pillars blown off.
DECORATIVE POST
West railing fell on bridge floor.
East railing fell into river.
RAILING DAMAGE SKETCH
CROSS SECTION OF CAST-IRON POSTS
RAILING DETAIL
Scale for all Details
26'-0"
24'-0"
2" Asphalt
6" Conc. slab
SECT. B-B
13'-0"
12'-0"
SECT. C-C
SECT. D-D
NOTES
1. Sections detailed show nearest steel cross member to that section.
2. Reinforced-conc. slab is supported directly by longitudinal steel girders.
3. Dimensions are only approximate.
SECRET
U.S. STRATEGIC BOMBING SURVEY
BRIDGE 23
HIROSHIMA, JAPAN GRID 4-H
FIGURE 10-XII

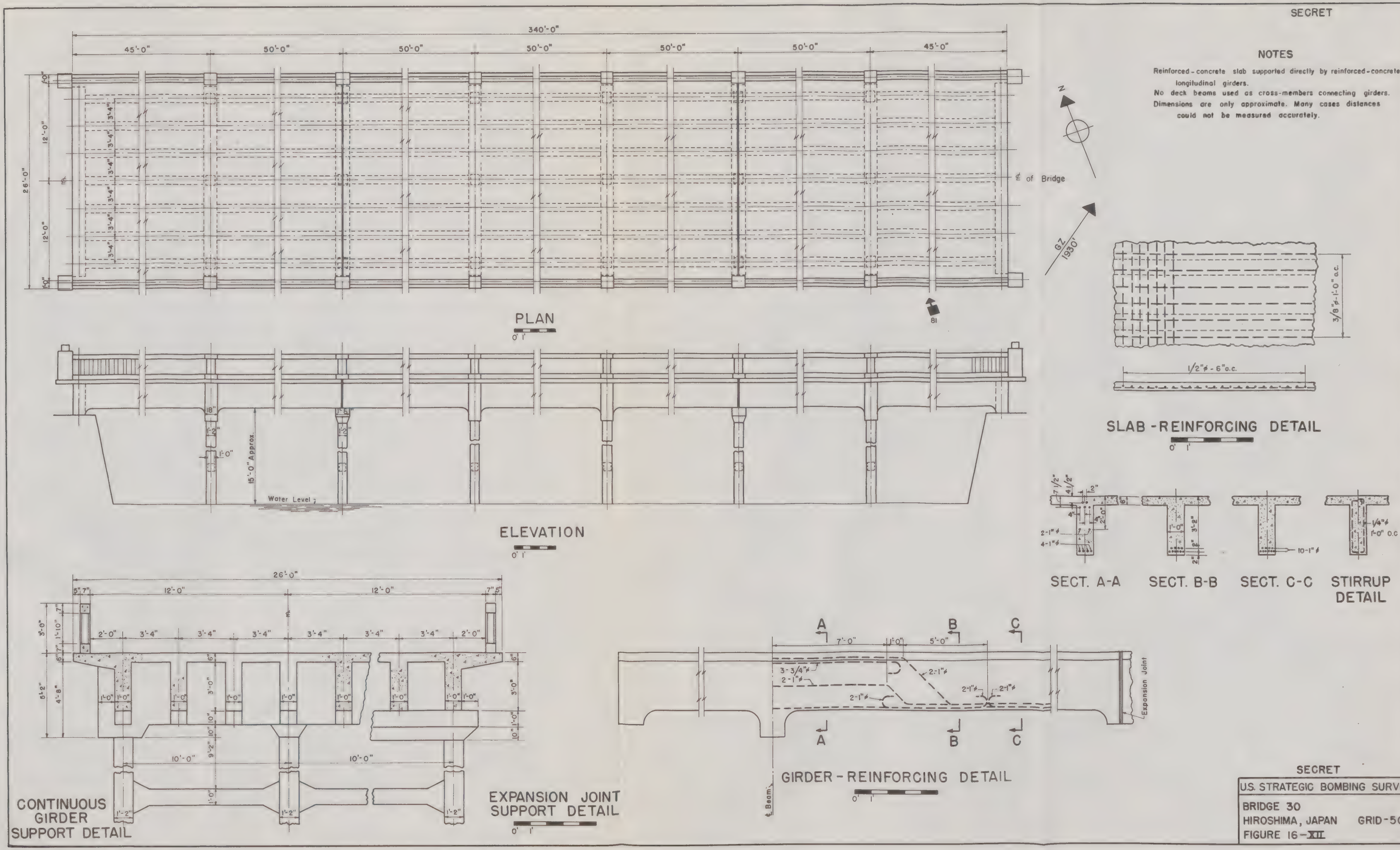

SECRET
℄ OF BRIDGE
4'-0 1/4"
8'-0 1/2"
8'-0 1/2"
8'-0 1/2"
8'-0 1/2"
8'-0 1/2"
50'-10"
50'-8"
72'-2"
65'-1 1/2"
65'-1 1/2"
51'-3"
50'-10"
CROSS BRACING AT TOP FLANGE ONLY
CROSS BRACING AT BOTTOM FLANGE ONLY
PLAN
0 5
G.Z. 1000'
N
50
70
OTA-GAWA
BRIDGE 24
BRIDGE 23
OTA-GAWA
MOTOYASU-GAWA
G Z
PLOT PLAN
NOTES
Reinforced-concrete slabs are supported directly by longitudinal steel girders.
Dimensions are approximate only. In many cases distances could not be measured accurately.
In many cases thickness of slab could not be determined accurately.
37" PLATE GIRDER
SEE DETAIL "A"
SEE DETAIL "B"
48" PLATE GIRDER
2-SPAN CONTINUOUS GIRDER
3-SPAN
CONTINUOUS
GIRDER
2-SPAN CONTINUOUS
GIRDER
ELEVATION
0 5
407'-0"
H.W.L.
L.W.L.
TRANSVERSE ELEVATION
3/4" JOINT FOR DETAIL "B" ONLY
3/8" WEB PLATE
8-4"X 6"X 1/2" STIFFENER ANGLES
℄ PIERS
3/8" COVER PLATE
4"X 6"X 1/2" FLANGE ANGLES
DETAIL "A" & "B"
SECRET
U.S. STRATEGIC BOMBING SURVEY
BRIDGE 24
HIROSHIMA, JAPAN GRID 4-H
FIGURE II-XII

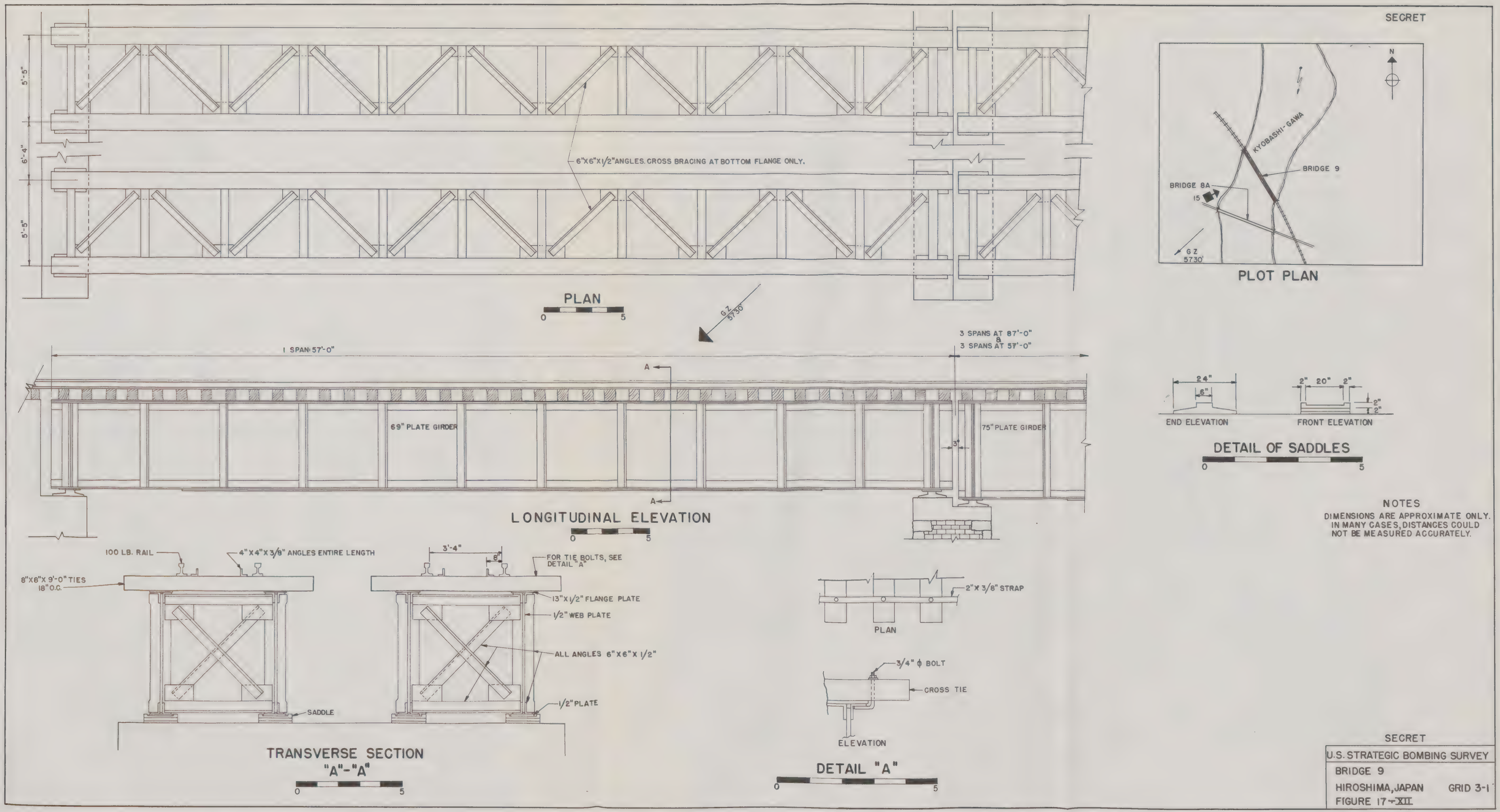

SECRET
FOR N.W. POST : CAP - BLOWN OFF ; "P" - NO MOVEMENT
N.E. " : " - MOVED 2" N. ; " - MOVED 2'-3" N.
S.E. " : " - NO MOVEMENT ; " - MOVED 1" E. AT 45° ANGLE
S.W. " : " - MOVED 2" S.E. ; " - MOVED 2" S.
℄ BRIDGE
9'-6
26'-6"
6" STONE CURB
7/8" ASPHALTIC CONCRETE BLOCKS
5" CONCRETE
1-1/2" ASPHALTIC CONCRETE BLOCKS
3 1/2"X 3 1/2"X 3/8" ANGLES
3"X8" CHANNEL
3 1/2"X 3 1/2"X 3/8" ANGLES
3/8" PLATE
10" CONCRETE
3/8" FILLER PLATE
3/8" PLATE
3/8"X14" COVER PLATE
4"X 6"X 1/2" FLANGE ANGLES
3/8" WEB PLATE
4"X 6"X 1/2" STIFFENER ANGLES
3"X 8" CHANNEL
3 1/2"X 3 1/2"X 3/8" ANGLES
THIS BRACING OCCURS AT EVERY OTHER CROSS MEMBER ONLY
2 - 1" PLATES
8'-0 1/2"
8'-0 1/2"
8'-0 1/2"
8'-0 1/2"
4'-0 1/4"
TRANSVERSE SECTION
36"
CAP
32"
STONE "P"
45"
54"
6"
4 1/2"
3"
1'-6"
4'-0"
10"
3'-2"
SECTION THRU POST AT BRIDGE ENDS
10"
52"
CURB LINE
3RD PIER FROM EAST ABUT
A
A
PLAN
4"
1'-1"
RUBBLE
RUBBLE
4'-8 1/2"
5'-0"
4'-8 1/2"
3'-6"
5"
3'-6"
1'-1"
4'-11"
4'-8"
6"
4'-4"
SOUTH
NORTH
SECTION SHOWING SLAB DAMAGE
ON NORTH SIDE BETWEEN FIRST & SECOND PIERS FROM WEST ABUTMENT
RUBBLE
ON SOUTH SIDE BETWEEN FIRST & SECOND PIERS FROM WEST ABUTMENT
3/8"φ-6" O.C.
1/4"φ-12" O.C.
1/2"φ-12" O.C.
3/8"φ-12" O.C.
TRANSVERSE RODS BENT DOWN OVER SUPPORTS SAME AS LONGITUDINAL RODS
12"
12"
12"
SIDEWALK SLAB
ROADWAY SLAB
REINFORCING DETAILS
10"
6'-0"
10"
8"
1"
6"
6"
2'-5"
6"
RAILING DETAIL
BLAST
W.L.
SKETCH OF BLAST REACTION TO BRIDGE STRUCTURE
4" C.I. SCUPPER
44"
8"
4" C.I.
24"
BRIDGE FLOOR
SECTION "A-A"
DETAIL OF SCUPPER DAMAGE
SECRET
U.S. STRATEGIC BOMBING SURVEY
BRIDGE 24
HIROSHIMA, JAPAN GRID 4-H
FIGURE 12-XII


SECRET
NOTES
Reinforced-concrete slab, supported directly by reinforced concrete longitudinal girders.
No deck beams used as cross-members connecting girders.
Dimensions are only approximate. Many cases distances could not be measured accurately.
In many cases thickness of slab could not be determined.
560'-0" Total Length
40'-0"
40'-0"
40'-0"
℄ of Bridge
South Abutment
12'-0"
13'-6"
At Every Other Pier
PLAN
A
A
GZ 5,200'
N
Continuous Girder
Continuous Girder
Continuous Girder
Continuous Girder
Continuous Girder
Destroyed
Damaged
WEST ELEVATION
Two Near Girders Destroyed
Scale for Plan, Elevation, & Section
0 1 2 3 4 5 6 7 8 9 Ft.
2'-4"
5"
℄ Of Each Span
5'-0"
ELEVATION
SECTION AA
2" A.C. Surface
12"x 18"
10'-0"
3'-0"
3'-10
12'-0"
SECTION OF GIRDER
3/4"ø
5/8"ø
ELEVATION OF GIRDER
STIRRUP
1/4"ø @ 12" O.C. Approx.
SLAB STEEL
3/8"ø Smooth 5" O.C. Long.
3/8"ø Smooth 16" O.C. Trans.
Scale for Girder Details
0 1 2 3 4 5 Ft.
SECRET
U.S. STRATEGIC BOMBING SURVEY
BRIDGE 25
HIROSHIMA, JAPAN GRID 3-H
FIGURE 13—XII


SECRET
NOTES
Wood deck supported directly by wooden stringers.
Wooden stringers are supported directly by built plate girder. (Transverse members)
Dimensions are only approximate. In many cases distances could not be measured accurately.
240'-0"
80'-0"
80'-0"
80'-0"
16" C.I. Pipe
PLAN
0' 2'
77
N
GZ 1190'
Pin-Connected, Steel Truss
H.W.L.
L.W.L.
6'-0"
ELEVATION
0' 2'
ISOMETRIC - SHOWING DAMAGE
DAMAGE: Bomb blast struck bridge from below after rebounding from water and also struck directly at sides causing failure in members and bridge to fall downstream.
1'-0"
3"x3"x3/8"∠
10"
1'-0"
5" Channel
1/4"x2" Lattice
3/8"x2" Lattice
SECT. A-A
A
2-1"x4" Bars
1-1"x4" Bar
2-1"x4" Bars Latticed
2-1"x4" Bars
2-1"x4" Bars
2-1"x4" Bars Latticed
12'-6"
2" A.C.
2'-2"x5'-10" Plate
4-1"x4" Bars
4-1"x4" Bars
4-1"x4" Bars
13'-0"
12'-6"
12'-6"
TRUSS
TYPICAL HALF SECTION
0' 1'
22'-0"
20'-0"
1/2"x4" Lattice
3" Pipe Railing
1'-0"
1'-4"
2'-2"
2'-2"
2'-2"
2'-2"
2'-2"
2'-2"
2'-2"
2'-2"
1'-4"
2" A.C.
4"x10"
16" C.I. Pipe
8 1/2"
1'-8"
4"x4"x1/2"∠
End Plate
1/2" Plate
3"x3"x3/8"∠
CROSS SECTION
0' 1'
SECRET
U.S. STRATEGIC BOMBING SURVEY
BRIDGE 29
HIROSHIMA, JAPAN GRID-5G
FIGURE 14-XII


SECRET
276'-0" Total Length
3 Spans Continuous
33'-0"
35'-0"
35'-0"
35'-0"
10'-8 1/2"
10'-8 1/2"
PLAN
0 1 2 3 4 5 ft.
GZ 7,130'
N
℄ of Bridge
ELEVATION
0 1 2 3 4 5 ft.
Sand Filled
SECTION AA
0 1 2 3 4 5 ft.
2" A.C. Surface
24'-6"
Simple Span
Continuous Girders
Continuous Girders
Simple Span
Abutment Destroyed
Damaged
Destroyed
Damaged
Spans Destroyed
EAST ELEVATION
Top of Slab
1/2" ø Stirrup
SECTION BB
2" A. C. Surface
3/8" ø @ 7" O.C.
3/8" ø @ 3" O.C.
1/2" ø Stirrup
SECTION CC
GIRDER & SLAB REINFORCING STEEL
0 1 2 3 4 5 ft.
NOTES
Reinforced-concrete slab, supported directly by reinforced concrete longitudinal girders.
No deck beams used as cross-members connecting girders.
Dimensions are only approximate. Many cases distances could not be measured accurately.
SECRET
U.S. STRATEGIC BOMBING SURVEY
BRIDGE 3
HIROSHIMA, JAPAN GRID 5-J
FIGURE 15 — XII

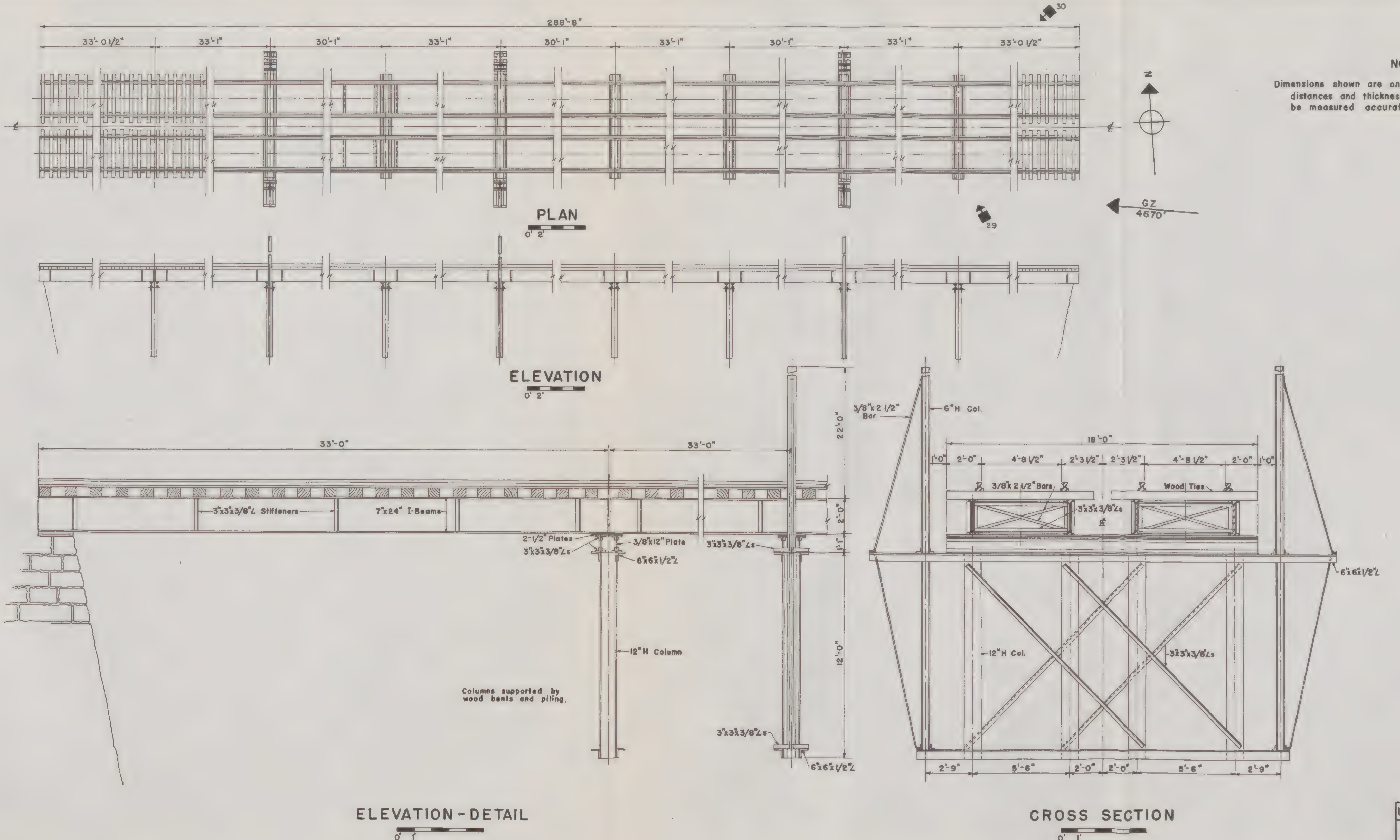

SECRET
NOTES
Reinforced-concrete slab supported directly by reinforced-concrete, longitudinal girders.
No deck beams used as cross-members connecting girders.
Dimensions are only approximate. Many cases distances could not be measured accurately.
340'-0"
45'-0"
50'-0"
50'-0"
50'-0"
50'-0"
50'-0"
45'-0"
26'-0"
12'-0"
12'-0"
3'-4"
℄ of Bridge
N
GZ 1930'
81
PLAN
ELEVATION
15'-0" Approx.
Water Level
SLAB-REINFORCING DETAIL
3/8"ϕ-1'-0" o.c.
1/2"ϕ-6" o.c.
SECT. A-A
SECT. B-B
SECT. C-C
STIRRUP DETAIL
10-1"ϕ
CONTINUOUS GIRDER SUPPORT DETAIL
EXPANSION JOINT SUPPORT DETAIL
10'-0"
10'-0"
GIRDER-REINFORCING DETAIL
7'-0"
1'-0"
5'-0"
3-3/4"ϕ
2-1"ϕ
Expansion Joint
℄ Beam
SECRET
U.S. STRATEGIC BOMBING SURVEY
BRIDGE 30
HIROSHIMA, JAPAN GRID-5G
FIGURE 16-XII


SECRET
5'-5"
6'-4"
5'-5"
6"X6"X1/2" ANGLES. CROSS BRACING AT BOTTOM FLANGE ONLY.
PLAN
0
5
G Z
5730'
1 SPAN: 57'-0"
3 SPANS AT 87'-0"
&
3 SPANS AT 57'-0"
A
69" PLATE GIRDER
75" PLATE GIRDER
3"
LONGITUDINAL ELEVATION
100 LB. RAIL
4"X4"X3/8" ANGLES ENTIRE LENGTH
8"X8"X 9'-0" TIES
18" O.C.
3'-4"
8"
FOR TIE BOLTS, SEE DETAIL "A"
13"X1/2" FLANGE PLATE
1/2" WEB PLATE
ALL ANGLES 6"X6"X 1/2"
1/2" PLATE
SADDLE
TRANSVERSE SECTION
"A"-"A"
2"X 3/8" STRAP
PLAN
3/4" ϕ BOLT
CROSS TIE
ELEVATION
DETAIL "A"
N
KYOBASHI-GAWA
BRIDGE 9
BRIDGE 8A
15
G Z
5730'
PLOT PLAN
24"
6"
END ELEVATION
2"
20"
2"
FRONT ELEVATION
DETAIL OF SADDLES
NOTES
DIMENSIONS ARE APPROXIMATE ONLY. IN MANY CASES, DISTANCES COULD NOT BE MEASURED ACCURATELY.
SECRET
U.S. STRATEGIC BOMBING SURVEY
BRIDGE 9
HIROSHIMA, JAPAN GRID 3-1
FIGURE 17-XII

SECRET

NOTES

Dimensions shown are only approximate. In many cases distances and thickness of steel members could not be measured accurately.

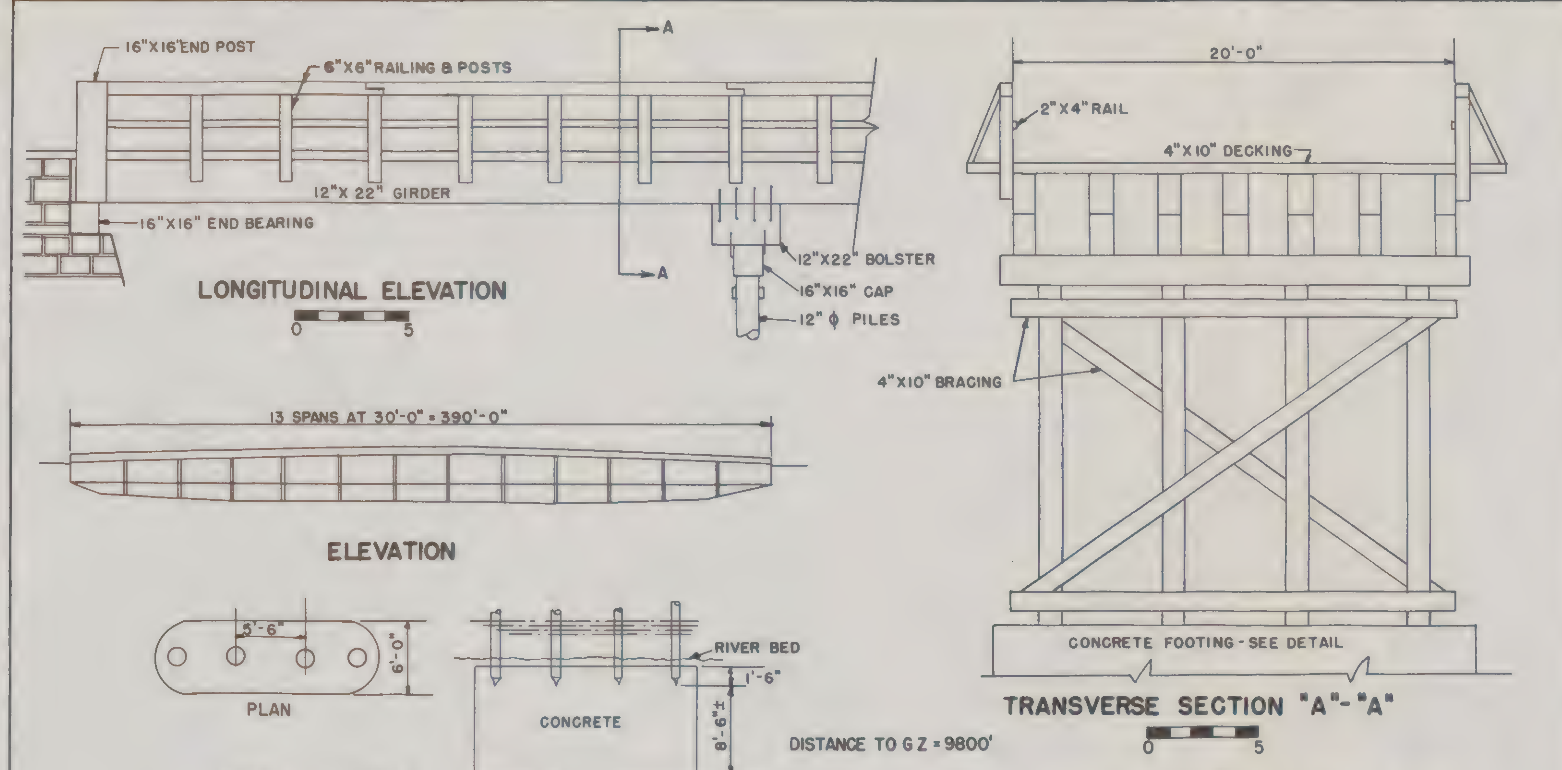


SECRET

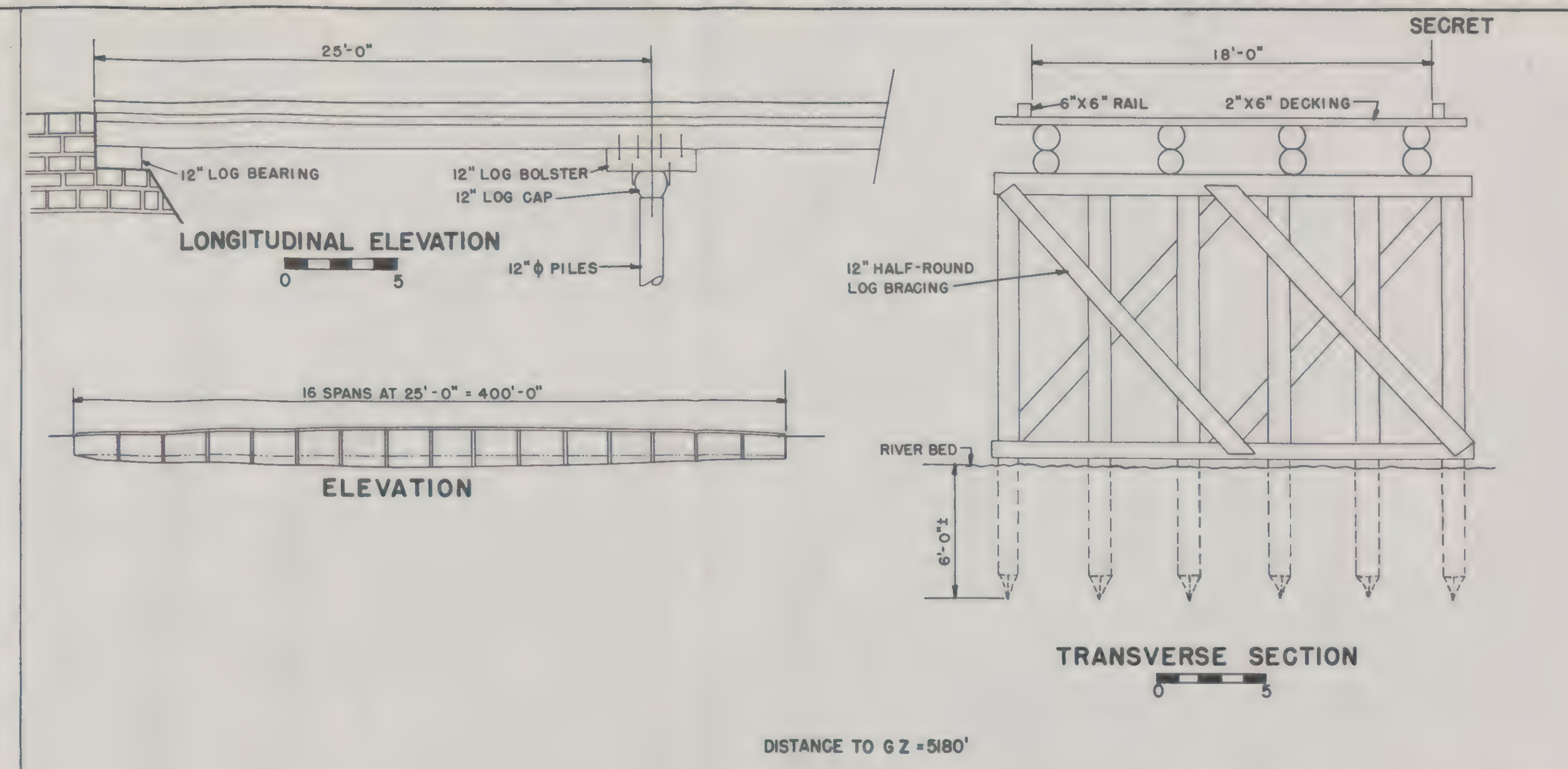
U.S. STRATEGIC BOMBING SURVEY

BRIDGE 13
HIROSHIMA, JAPAN GRID-5I
FIGURE 18-XII

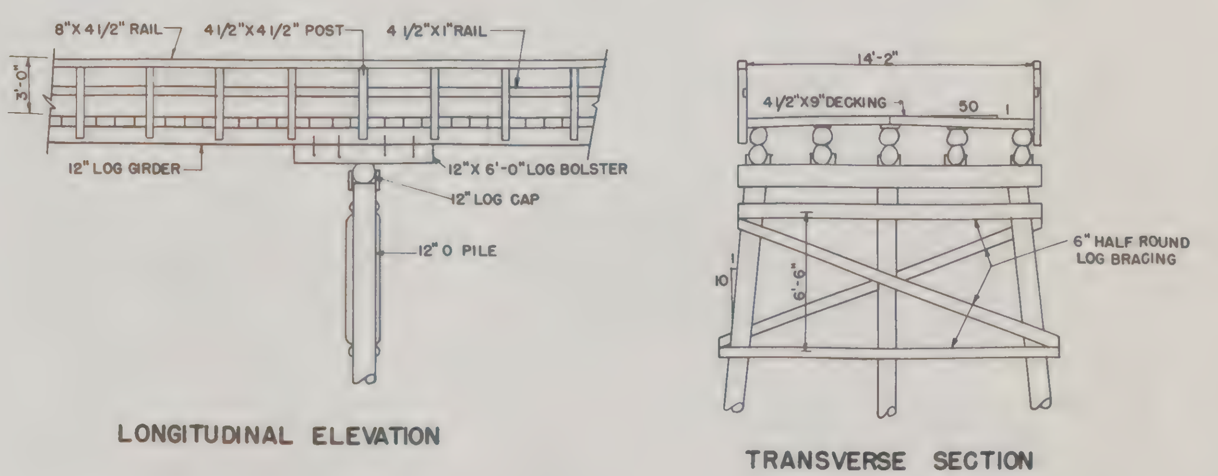
SECRET



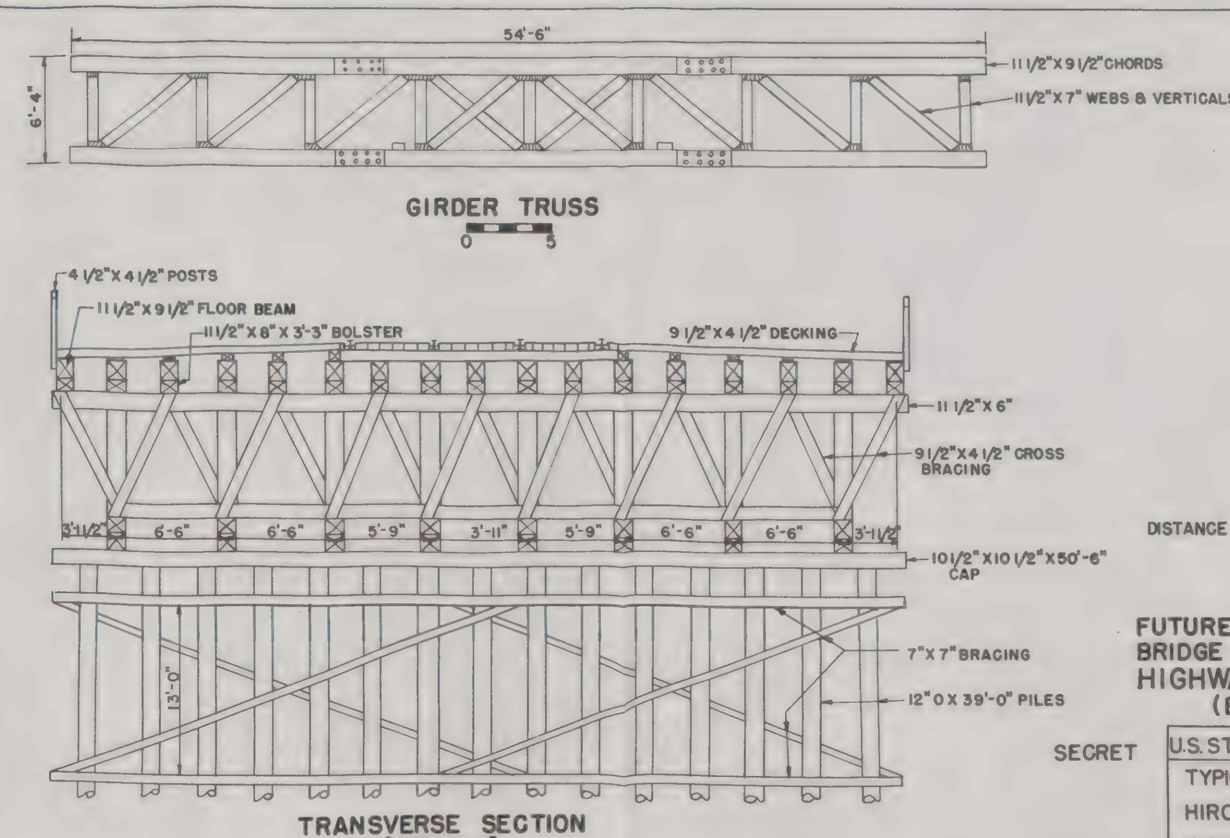
TYPICAL EXISTING TIMBER BRIDGE. (BRIDGE 1)



TYPICAL TIMBER BRIDGE ERECTED FOR URGENT USE. (BRIDGE 43)



SKETCH OF FUTURE STANDARD WOOD BRIDGE CONSTRUCTION.



FUTURE TYPICAL TIMBER BRIDGE CONSTRUCTION FOR HIGHWAY & TROLLEY TRAFFIC. (BRIDGE 28)

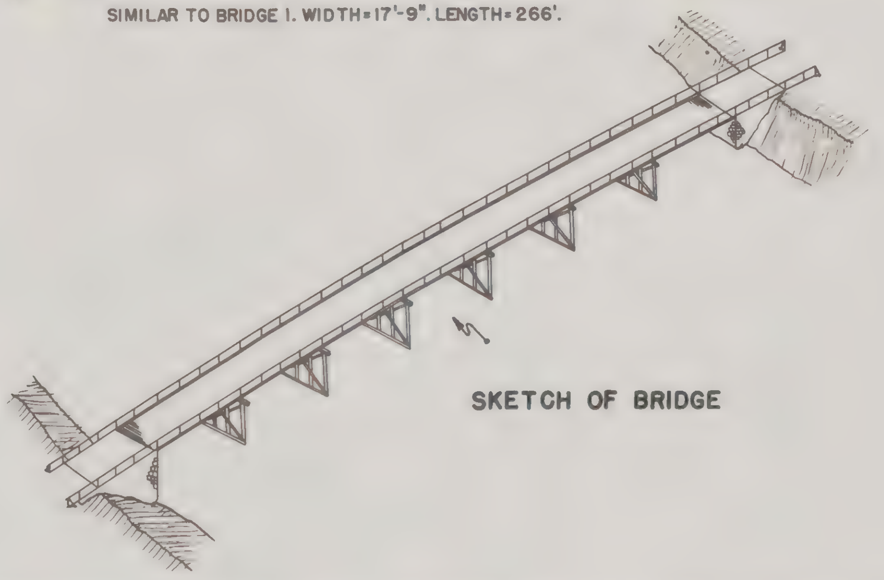
SECRET

U.S. STRATEGIC BOMBING SURVEY
TYPICAL TIMBER BRIDGES
HIROSHIMA, JAPAN
FIGURE 19 - XII

731568 O - 47 (Face p. 118) No. 13

BRIDGE 6

SIMILAR TO BRIDGE 1. WIDTH=17'-9". LENGTH=266'.



SKETCH OF BRIDGE

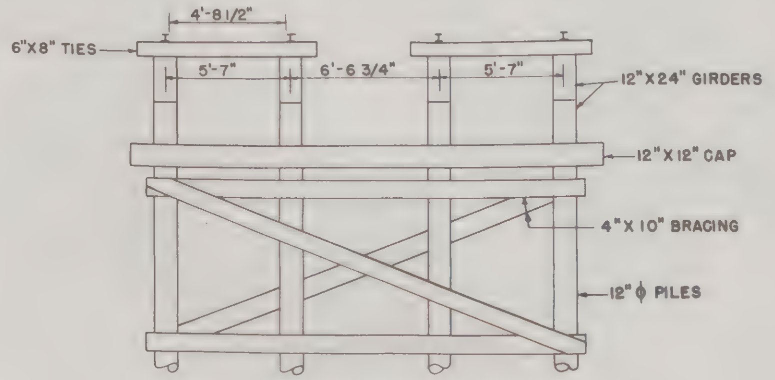
BRIDGE 11

SUSPENSION SPAN=220'. WIDTH=9'. CABLES=3 1/2".
FOR DETAILS, PHOTOS 19 TO 23.

ELEVATION SKETCH

BRIDGE 13A

9 SPANS AT 33'. LENGTH=307'. SECTION AS SHOWN BELOW.



SKETOH OF TRANSVERSE SECTION

BRIDGE 14

SIMILAR TO BRIDGES 1 & 6.
10 SPANS AT 30'. LENGTH=300'.
WIDTH=19'-9".

BRIDGE 15

SIMILAR TO BRIDGES 1 & 6.
14 4-PILE BENTS. LENGTH=309'.
WIDTH=19'. 7 12"X 22" GIRDERS.

BRIDGE 18

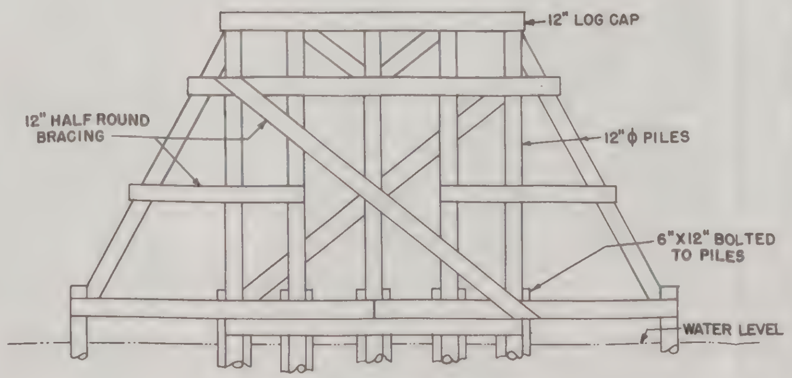
SIMILAR TO BRIDGES 1 & 6.
15 4-PILE BENTS. LENGTH=448'.
WIDTH=19'. 7 12"X22" GIRDERS.

BRIDGE 21

SIMILAR TO BRIDGE 43.
9 7-PILE BENTS. LENGTH=295'.
WIDTH=32'-10". 12 10" LOG GIRDERS.
BENTS SKEWED APPROX. 15° TO LONGITUDINAL ℄ OF BRIDGE.

BRIDGE 32

SIMILAR TO BRIDGE 43.
29 5-PILE BENTS. LENGTH=660'.
WIDTH=18'. 7 12" LOG GIRDERS.
6" EARTH ROADWAY ON 4" LOG DECK.
ADDITIONAL BRACING TO PILES IN BENTS.
SKETCH BELOW.



SKETCH OF PILE BENTS

BRIDGE 34

SIMILAR TO BRIDGES 1 & 6.
11 4-PILE BENTS. LENGTH=312'.
WIDTH=17'-10".

BRIDGE 36

SIMILAR TO "FUTURE STANDARD" BRIDGE.
6 3-PILE BENTS. LENGTH=175'.
WIDTH=10'.

BRIDGE 38

SIMILAR TO BRIDGES 1 & 6.
10 4-PILE BENTS. LENGTH=330'.
WIDTH=12'-1".

BRIDGE 39

SIMILAR TO BRIDGES 1 & 6.
15 4-PILE BENTS. LENGTH=415'.
WIDTH=16'-9".

BRIDGE 40

SIMILAR TO "FUTURE STANDARD" BRIDGE.
18 4-PILE BENTS. LENGTH=421'.
WIDTH=17'-11".

BRIDGE 42

SIMILAR TO "FUTURE STANDARD" BRIDGE.
13 4-PILE BENTS. LENGTH=421'.
WIDTH=17'-11".

BRIDGE 46

SIMILAR TO BRIDGES 1 & 6.
9 4-PILE BENTS. LENGTH=220'.
WIDTH=13'-1".

BRIDGE 49

SIMILAR TO "FUTURE STANDARD" BRIDGE.
10 2-PILE BENTS. LENGTH=163'.
WIDTH=3'.

NOTES FOR TIMBER BRIDGES

1. FOR BRIDGES 1, 43 & "FUTURE STANDARD", FIGURE 19.
2. IN MANY CASES, THE ACCURATE NUMBER OF SPANS COULD NOT BE DETERMINED AND THE APPROXIMATE LENGTH OF BRIDGE COULD NOT BE MEASURED BECAUSE OF MISSING SPANS DUE TO DAMAGE.

SECRET

U.S. STRATEGIC BOMBING SURVEY
TIMBER BRIDGES
HIROSHIMA, JAPAN
FIGURE 20-XII

USE: Highway and pedestrian.
DESIGN TYPE: Reinforced concrete.
MATERIALS USED:
- Longitudinal member: Five reinforced-concrete beams 13 by 27 inches per span.
- Decking: Seven-inch reinforced concrete with 1½-inch asphalt wearing surface.
- Abutments: Concrete.
- Piers: Concrete.

SPECIAL FEATURES: Beams haunched at supports.
HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: More massive. Generally, the bridges were designed to carry lower loadings than is American practice.
QUALITY OF CONSTRUCTION AND MATERIALS: The design, details and arrangements of the bridge were below United States standards. Quality of materials good.
DAMAGE—EXTENT: Severe. Spans and piers adjacent to south abutment severely damaged.
CAUSE: Flood.
REPAIR AND SALVAGE:
EXTENT USABLE:
- Spans: Five.
- Piers: Five.
- Abutments: One.

REPAIRS NECESSARY TO PLACE IN SERVICE:
- Temporary: Four spans required with three piers and one abutment.
- Permanent: Five spans required with four piers and one abutment.

REMARKS: Carrying a 16-inch water main along the east side by bents.
PHOTOGRAPHS:

No.	*Direction and title*
4	Looking west at flood damage of highway bridge over the Enko-Gawa.
5	Deck girder reinforcing steel.
6	Damaged concrete girders.
7	Steel reinforcement in concrete deck.

BRIDGE 4

Coordinates: 5J

Over River: Enko-Gawa.
Distance from "Zero Point": Plan, 6,450; slant, 6,750.
USE: Highway, pedestrian and trolley.
DESIGN TYPE: Reinforced concrete.
MATERIALS USED:
- Longitudinal member: Fourteen reinforced-concrete beams, 12 by 30 inches per span.
- Decking: Seven-inch reinforced concrete with asphalt wearing surface.
- Abutments: Concrete.
- Piers: Concrete with stone masonry at corners.

SPECIAL FEATURES: Piers arched. Longitudinal beams adjacent to abutments are straight. All others are haunched except at piers nearest to abutments which are hinged.
HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: More massive. Generally, the bridges were designed to carry lower loadings than is American practice.
QUALITY OF CONSTRUCTION AND MATERIALS: The design, details, and arrangements of the bridge were below United States standards. Quality of materials good. Railings not doweled.
DAMAGE—EXTENT: None, except partly damaged concrete railings along the north and south elevation.
CAUSE: Blast.
REPAIR AND SALVAGE:
EXTENT USABLE:
- Spans: All.
- Piers: All.
- Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:
- Temporary: None.
- Permanent: Replace damage railings and patch asphalt wearing surface.

REMARKS: Carrying a double-track trolley. Blast strong enough to blow pedestrians to deck and into river, and force autos to curbs. Trolley cars on bridge remained on tracks.
PHOTOGRAPHS:

No.	*Direction and title*
8	Looking south at north elevation of reinforced-concrete bridge over the Enko-Gawa. Superficial blast damage at northeast corner concrete railing.
9	Southeast corner of east abutment.

BRIDGE 5

Coordinates: 5J

Over River: Enko-Gawa.
Distance from "Zero Point": Plan, 6,210; slant, 6,510.

USE: Highway and pedestrian.
DESIGN TYPE: Reinforced concrete.
MATERIALS USED:
Longitudinal member: Seven reinforced-concrete beams 15 by 27 inches per span.
Decking: Reinforced concrete with asphalt-wearing surface.
Abutments: Concrete.
Piers: Concrete with stone masonry at corners.
SPECIAL FEATURES: Longitudinal beams haunched at supports.
HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: More massive. Generally, the bridges were designed to carry lower loadings than is American practice.
QUALITY OF CONSTRUCTION AND MATERIALS: The design, details and arrangements of the bridge were below United States standards. Quality of materials good.
DAMAGE—EXTENT: None.
CAUSE: None.
REPAIR AND SALVAGE:
EXTENT USABLE:
Spans: All.
Piers: All.
Abutments: Both.
REPAIRS NECESSARY TO PLACE IN SERVICE:
Temporary: None.
Permanent: None.
REMARKS: Structure well protected from the blast.
PHOTOGRAPHS:

No.	Direction and title
10	Looking north at south elevation of reinforced-concrete bridge over the Enko-Gawa. No damage. Note.—Bridge 5A (steel-truss) north of Bridge 5.

BRIDGE 5A

Coordinates: 5J

Over River: Enko-Gawa.
Distance from "Zero Point": Plan, 6,160; slant, 6,470.
USE: Water crossing.
DESIGN TYPE: Steel-truss.
MATERIALS USED:
Longitudinal member: 3- by 3- by 1/4-inch angles.
Decking: 3- by 3- by 1/4-inch angles and 2 by 1/4-inch bars comprising the steel bracing.
Abutments: Concrete with masonry.
Piers: Concrete.
SPECIAL FEATURES: Top and bottom chords parallel.
HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Bridges would carry normal aqueduct loadings. Comparable with similar structures in the United States.
QUALITY OF CONSTRUCTION AND MATERIALS: Comparable with similar structures in United States. Materials good for concrete and masonry.
DAMAGE—EXTENT: None.
CAUSE: None.
REPAIR AND SALVAGE:
EXTENT USABLE:
Spans: All.
Piers: All.
Abutments: Both.
REPAIRS NECESSARY TO PLACE IN SERVICE:
Temporary: None.
Permanent: None.
REMARKS: Aqueduct carrying 16-inch water main.
PHOTOGRAPHS:

No.	Direction and title
10	Steel-truss aqueduct south of Bridge 5. No damage.

BRIDGE 6

Coordinates: 4I

Over River: Enko-Gawa.
Distance from "Zero Point": Plan 5,370; slant 5,730.
USE: Highway and pedestrian.
DESIGN TYPE: Timber superstructure on pile bents.
MATERIALS USED:
Longitudinal member: Seven timber beams per span.
Decking: Timber.
Abutments: Concrete.
Piers: Four piles bent.
SPECIAL FEATURES: None.
HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Not ascertainable.

QUALITY OF CONSTRUCTION AND MATERIALS: Not ascertainable.
DAMAGE—EXTENT: Complete destruction.
CAUSE: Initially damaged by blast at approximate bridge center, later totally destroyed by fire.
REPAIR AND SALVAGE:
EXTENT USABLE:
Spans: None.
Piers: None.
Abutments: Both.
REPAIRS NECESSARY TO PLACE IN SERVICE:
Temporary:
Permanent: New bridge required.
REMARKS: Constant replacement of piling required after floods.
PHOTOGRAPHS:

No.	*Direction and title*
11	Looking south at remains of bridge over the Enko-Gawa destroyed by blast and flood.

BRIDGE 7

Coordinates: 4I

Over River: Kyobashi-Gawa.
Distance from "Zero Point": Plan 5,200; slant 5,570.
USE: Highway and pedestrian.
DESIGN TYPE: Reinforced concrete.
MATERIALS USED:
Longitudinal member: Six reinforced-concrete beams, 16 by 20 inches per span.
Decking: Reinforced concrete with asphalt wearing surface.
Abutments: Concrete.
Piers: Concrete bents.
SPECIAL FEATURES: Slight intrado effect. Longitudinal beams were haunched at supports.
HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Below United States standards principally because of lower design loads.
QUALITY OF CONSTRUCTION AND MATERIALS: The design, details and arrangements of the bridge structure were below United States standards. Quality of materials good.
DAMAGE—EXTENT: None.
CAUSE: None.
REPAIR AND SALVAGE:
EXTENT USABLE:
Spans: All.
Piers: All.
Abutments: Both.
REPAIRS NECESSARY TO PLACE IN SERVICE:
Temporary: None.
Permanent: None.
REMARKS: Structure well protected from blast.
PHOTOGRAPHS:

No.	*Direction and title*
12	Looking west between reinforced-concrete, undamaged bridge and steel-truss aqueduct over the Kyobashi-Gawa.

BRIDGE 7A

Coordinates: 4I

Over River: Kyobashi-Gawa.
Distance from "Zero Point": Plan, 5,240; slant, 5,600.
USE: Water crossing.
DESIGN TYPE: Steel truss.
MATERIALS USED:
Longitudinal member: 4- by 6- by 3/8-inch angles.
Decking: 3 by 3 feet by 3/8-inch angles by 2- by 2- by 3/8-inch angles, also 3- by 6- by 1/2-inch angles with piers, comprising bracing.
Abutments: Concrete faced with stone and brick masonry.
Piers: Concrete.
SPECIAL FEATURES: Top and bottom chords parallel.
HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Bridges would carry normal aqueduct loadings. Comparable with similar structures in United States.
QUALITY OF CONSTRUCTION AND MATERIALS: Comparable with similar structures in United States. Materials good for concrete and masonry.
DAMAGE—EXTENT: None.
CAUSE: None.
REPAIR AND SALVAGE:
EXTENT USABLE:
Spans: All.
Piers: All.
Abutments: Both.
REPAIRS NECESSARY TO PLACE IN SERVICE:
Temporary: None.
Permanent: None.

REMARKS: Aqueduct carrying 22-inch water main. Sheet-metal covering blown from pipe.

PHOTOGRAPHS:

No.	Direction and title
12	Looking west between reinforced-concrete Bridge 7 and steel aqueduct Bridge 7A over the Kyobashi-Gawa. No damage.

BRIDGE 8

Coordinates: 4I

Over River: Kyobashi-Gawa.

Distance from "Zero Point": Plan, 5,390; slant, 5,700.

USE: Highway and pedestrian.

DESIGN TYPE: Reinforced concrete.

MATERIALS USED:

Longitudinal member: Five reinforced-concrete beams, 12- by 20-inch, per span.

Decking: Reinforced concrete with asphalt wearing surface.

Abutments: Concrete.

Piers: Concrete bents.

SPECIAL FEATURES: Longitudinal beams were haunched at supports. Piers haunched at pier caps.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Below United States standards principally because of lower design loads.

QUALITY OF CONSTRUCTION AND MATERIALS: The design, details, and arrangements of the bridge structure were below United States standards. Quality of materials good.

DAMAGE—EXTENT: None, except railings totally destroyed along both elevations. Asphalt surface very badly pocketed.

CAUSE: Blast.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: All.

Piers: All.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary: None.

Permanent: Replace destroyed concrete railings and patch asphalt wearing surface.

REMARKS: Pedestrians blown into river by blast. Automobiles traveling along the bridge not disturbed by blast.

PHOTOGRAPHS:

No.	Direction and title
13	Looking north at south elevation of bridge over Kyobashi-Gawa. Superficial blast damage to concrete railings.

BRIDGE 8A

Coordinates: 4I

Over River: None.

Distance from "Zero Point": Plan, 5,580; slant, 5,900.

USE: Railroad.

DESIGN TYPE: I-beam girder.

MATERIALS USED:

Longitudinal member: 24-inch I-beam with angle stiffeners.

Decking: Ties and rails.

Abutments: Concrete.

Piers: None.

SPECIAL FEATURES: None.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Bridge would carry normal railroad loadings. Comparable with similar structures in United States.

QUALITY OF CONSTRUCTION AND MATERIALS: Comparable with similar structures in United States. Materials good for concrete and masonry.

DAMAGE—EXTENT: None.

CAUSE: None.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: Entire single span.

Piers: None used.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary: None.

Permanent: None.

REMARKS: Carrying a double-track railroad line, and forms an underpass for highway and pedestrian traffic.

PHOTOGRAPHS:

No.	Direction and title
14	Looking north at undamaged, steel-girder, I-beam railroad bridge.

BRIDGE 9

Coordinates: 3I

Over River: Kyobashi-Gawa.

Distance from "Zero Point": Plan, 5,730; slant, 6,050.

USE: Railroad.
DESIGN TYPE: Plate girder.
MATERIALS USED:
Longitudinal member: 69 and 75 inches in depth.
Decking: Ties and rails.
Abutments: Concrete.
Piers: Concrete. Faced with stone and brick masonry at corners.
SPECIAL FEATURES: Skewed at approximately 45°.
HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Bridges would carry normal railroad loadings. Comparable with similar structures in United States.
QUALITY OF CONSTRUCTION AND MATERIALS: Comparable with similar structures in United States. Materials good for concrete and masonry.
DAMAGE—EXTENT: No structural damage to girders. Only discolored paint due to bomb effects along the south side. North face not affected.
CAUSE: None.
REPAIR AND SALVAGE:
EXTENT USABLE:
Spans: All.
Piers: All.
Abutments: None.
REPAIRS NECESSARY TO PLACE IN SERVICE:
Temporary: None.
Permanent: None.
REMARKS: Carrying a double-track railroad line.
PHOTOGRAPHS:

No.	*Direction and title*
15	South elevation of undamaged double-track railroad bridge over the Kyobashi-Gawa.
16	Paint on south elevation of steel girder discolored by exposure to bomb effects.
17	Paint on north elevation of steel girder unaffected by bomb effects.

BRIDGE 10

Coordinates: 3I

Over River: Kyobashi-Gawa.
Distance from "Zero Point": Plan, 6,950; slant, 7,250.
USE: Highway and pedestrian.
DESIGN TYPE: Reinforced concrete.
MATERIALS USED:
Longitudinal member: Five reinforced-concrete beams, 13 by 30 inches per span.
Decking: Reinforced concrete with asphalt wearing surface.
Abutments: Concrete.
Piers: Concrete bents.
SPECIAL FEATURES: Longitudinal beams haunched at supports.
HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Below United States standards principally because of lower design loads.
QUALITY OF CONSTRUCTION AND MATERIALS: The design, details, and arrangements of the bridge structure were below United States standards. Quality of materials good.
DAMAGE—EXTENT: Moderate. The pier and spans adjacent to the south abutment were caused to settle.
CAUSE: Flood.
REPAIR AND SALVAGE:
EXTENT USABLE:
Spans: All.
Piers: All.
Abutments: Both.
REPAIRS NECESSARY TO PLACE IN SERVICE:
Temporary: None.
Permanent: One pier and two spans.
REMARKS: Carrying a 20-inch water main along the west side. Bridge opened to light traffic.
PHOTOGRAPHS:

No.	*Direction and title*
18	Looking west at east elevation of bridge over the Kyobashi-Gawa showing moderate flood damage.

BRIDGE 11

Coordinates: 2I

Over River: Kyobashi-Gawa.
Distance from "Zero Point": Plan, 7,960; slant, 8,200.
USE: Pedestrian.
DESIGN TYPE: Cable suspension.
MATERIALS USED:
Longitudinal member: Steel cable.
Decking: Timber, 1¼ by 6 inches.
Abutments: Concrete.
Piers: None.

SPECIAL FEATURES: Unusual suspension and vertical members. Eyes and hooks form connection of crude type at ends of suspension cables.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Below United States standards; lower design loads.

QUALITY OF CONSTRUCTION AND MATERIALS: The design, details and arrangements of the bridge structure were below United States standards. Quality of materials fair.

DAMAGE—EXTENT: None.

CAUSE: None.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: The single suspension.

Piers: None.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary: None.

Permanent: None.

REMARKS: Constructed by the Japanese Army.

PHOTOGRAPHS:

No.	*Direction and title*
19	Looking southwest at corner of north abutment.
20	Cable-tied vertical member, west suspension cable.
21	Looking west at east suspension cable, undamaged.
22	Underside of deck structure.
23	Cable-tied vertical member of west suspension cable.

BRIDGE 12

Coordinates: 5I

Over River: Kyobashi-Gawa.

Distance from "Zero Point": Plan, 4,700; slant, 5,100.

USE: Highway and pedestrian.

DESIGN TYPE: Plate girder.

MATERIALS USED:

Longitudinal member: Thirty-six inches in depth.

Decking: Reinforced concrete with asphalt wearing surface.

Abutments: Concrete.

Piers: Concrete with stone facing at corners.

SPECIAL FEATURES: Longitudinal girders haunched at supports. Ornamental stone facing on external girders.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: More massive. Generally, the bridges were designed to carry lower loadings than is American practice.

QUALITY OF CONSTRUCTION AND MATERIALS: The design, details and arrangements of the bridge were below United States standards. Quality of material good for concrete.

DAMAGE—EXTENT: No structural damage to girders. Ornamental stone posts at the southeast and southwest, corners slightly dislodged.

CAUSE: Blast.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: All.

Piers: All.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary: None.

Permanent: Repair dislodged ornamental stone posts. Patch asphalt wearing surface.

REMARKS: Carrying a 16-inch water main.

PHOTOGRAPHS:

No.	*Direction and title*
24	South elevation of bridge over the Kyobashi-Gawa.
25	Ornamental stone post at southwest corner dislodged by blast.
26	Ornamental stone post at southeast corner dislodged by blast.

BRIDGE 13

Coordinates: 5I

Over River: Kyobashi-Gawa.

Distance from "Zero Point": Plan, 4,670; slant, 5,080.

USE: Trolley.

DESIGN TYPE: Plate girder (I-beam).

MATERIALS USED:

Longitudinal member: 24-inch I-beam with angle stiffeners.

Decking: Ties and rails.

Abutments: Stone.

Piers: Four H-columns bent with angle bracing.

SPECIAL FEATURES: Additional timber column bents with timber bracing added to each bent. H-columns with angle extension fastened to steel bents to carry electrical overhead service.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Below United States standards; lower design loads.

QUALITY OF CONSTRUCTION AND MATERIALS: The design, details and arrangements of the bridge structure were below United States standards. Quality of material fair for timber.

DAMAGE—EXTENT: Slight deflection to several main members. Slight damage to center spans. Moderate damage to several of the spans and bents along the bridge structure.

CAUSE: Blast and flood.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: All.

Piers: All.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary: Build up four center bents with timber cribbing to normal elevation of trolley tracks.

Permanent: Replace four center bents and reset 24-inch I-section girder to normal alignment and elevation.

REMARKS: Carrying a double-track trolley line. Bridge was repaired and used during this survey. An S-curve slope existed in trolley rails across the bridge spans.

PHOTOGRAPHS:

No.	Direction and title
27	Timber cribbing under trolley tracks at fourth span from east abutment of blast- and flood-damaged bridge over the Kyobashi-Gawa.
28	Looking west at cribbing under trolley tracks at fifth span from east abutment.
29	South elevation of trolley bridge.
30	Flood and blast damage to bridge.

BRIDGE 13–A

Coordinates: 5I

Over River: Kyobashi-Gawa.

Distance from "Zero Point": Plan, 4,670; slant, 5,080.

USE: Double-track trolley.

DESIGN TYPE: Timber superstructure on pile bents.

MATERIALS USED:

Longitudinal member: Four timber beams, 16 by 20 inches per span.

MATERIALS USED—Continued

Decking: Timber ties and rails.

Abutments: Stone masonry.

Piers: Four piles bent.

SPECIAL FEATURES: Timber extended over abutments and set on soil without sills.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Not ascertainable.

QUALITY OF CONSTRUCTION AND MATERIALS: Not ascertainable.

DAMAGE—EXTENT: Complete destruction.

CAUSE: Span adjacent to east abutment initially damaged by blast, later bridge totally destroyed by fire.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: None.

Piers: None.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary:

Permanent: New bridge required.

REMARKS: Constant replacement of piling required after floods.

PHOTOGRAPHS:

No.	Direction and title
31	Looking east at blast- and fire-destroyed timber bridge over the Kyobashi-Gawa.
32	Looking north. Destroyed by blast and fire.

BRIDGE 14

Coordinates: 5I

Over River: Kyobashi-Gawa.

Distance from "Zero Point": Plan, 4,760; slant, 5,170.

USE: Pedestrian.

DESIGN TYPE: Timber superstructure on pile bents.

MATERIALS USED:

Longitudinal member: Timber girders.

Decking: Timber.

Abutments: Stone masonry.

Piers: Four piles bent.

SPECIAL FEATURES: None.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Not ascertainable.

QUALITY OF CONSTRUCTION AND MATERIALS: Not ascertainable.

DAMAGE—EXTENT: Complete destruction.

CAUSE: By spreading of fires from adjacent buildings.
REPAIR AND SALVAGE:
EXTENT USABLE:
Spans: None.
Piers: None.
Abutments: Both.
REPAIRS NECESSARY TO PLACE IN SERVICE:
Temporary:
Permanent: New bridge required.
REMARKS: Constant replacement of piling required after floods.
PHOTOGRAPHS:

No.	*Direction and title*
33	Looking north at west abutment of fire destroyed bridge over the Kyobashi-Gawa.

BRIDGE 15

Coordinates: 6I

Over River: Kyobashi-Gawa.
Distance from "Zero Point": Plan, 5,580; slant, 5,900.
USE: Highway and pedestrian.
DESIGN TYPE: Timber superstructure on pile bents.
MATERIALS USED:
Longitudinal member: Seven timber beams, 12 by 22 inch per span.
Decking: 4 by 10 inches.
Abutments: Concrete.
Piers: Four piles (12-inch diameter) per bent.
SPECIAL FEATURES: Used stapled connections rather than steel bolt.
HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Below United States standards; lower design loads.
QUALITY OF CONSTRUCTION AND MATERIALS: The design, details, and arrangements of the bridge structure were below United States standards. Quality of material fair.
DAMAGE—EXTENT: None.
CAUSE: None.
REPAIR AND SALVAGE:
EXTENT USABLE:
Spans: All.
Piers: All.
Abutments: Both.
REPAIRS NECESSARY TO PLACE IN SERVICE:
Temporary: None.
Permanent: None.
REMARKS: Bridge being used but timber decking decaying.
PHOTOGRAPHS:

No.	*Direction and title*
34	Looking south at undamaged bridge over the Kyobashi-Gawa.

BRIDGE 16

Coordinates: 6I

Over River: Kyobashi-Gawa.
Distance from "Zero Point": Plan, 5,750; slant, 6,100.
USE: Highway and pedestrian.
DESIGN TYPE: Reinforced concrete.
MATERIALS USED:
Longitudinal member: Fourteen reinforced-concrete beams, 13 by 33 inch, per span.
Decking: Reinforced concrete with asphalt wearing surface.
Abutments: Concrete.
Piers: Concrete with stone masonary at corners.
SPECIAL FEATURES: Some of the longitudinal beams were haunched at supports.
HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: More massive. Generally, the bridges were designed to carry lower loadings than is American practice.
QUALITY OF CONSTRUCTION AND MATERIALS: The design, details, and arrangements of the bridge structure were below United States standards. Quality of material good.
DAMAGE—EXTENT: None.
CAUSE: None.
REPAIR AND SALVAGE:
EXTENT USABLE:
Spans: All.
Piers: All.
Abutments: Both.
REPAIRS NECESSARY TO PLACE IN SERVICE:
Temporary: None.
Permanent: None.
REMARKS: Structure fairly protected from blast.
PHOTOGRAPHS:

No.	*Direction and title*
35	Looking south showing the north elevation of undamaged reinforced-concrete highway bridge over the Kyobashi-Gawa.

BRIDGE 17

Coordinates: 7H

Over River: Kyobashi-Gawa.

Distance from "Zero Point": Plan, 7,600; slant, 8,870.

USE: Highway, pedestrian and trolley.

DESIGN TYPE: Plate girder.

MATERIALS USED:

Longitudinal member: 54 inches in depth.

Decking: Reinforced concrete with asphalt wearing surface.

Abutments: Concrete with stone facing.

Piers: Concrete with stone facing.

SPECIAL FEATURES: Girders haunched and anchored to pin-connected rockers at piers. Stone masonry approach spans.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: More massive. Generally, the bridges were designed to carry lower loadings than is American practice.

QUALITY OF CONSTRUCTION AND MATERIALS: The railings not doweled. The design, details and arrangements of the bridge structure were below United States standards. Quality of materials good for concrete and stone masonry.

DAMAGE—EXTENT: No structural damage to girders. Railings of main spans destroyed. Approach spans railings not damaged.

CAUSE: Blast.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: All.

Piers: All.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary: None.

Permanent: Replace damaged concrete railings.

REMARKS: Carrying double-track trolley line. Carrying 12-inch water main. No vehicles or pedestrians on structure during blast.

PHOTOGRAPHS:

No.	*Direction and title*
36	Looking south at trolley and highway, plate-girder bridge over the Kyobashi-Gawa. Superficial damage to concrete railings by blast.

BRIDGE 18

Coordinates: 7G

Over River: Motoyasu-Gawa.

Distance from "Zero Point": Plan, 6,000; slant, 6,300.

USE: Highway and pedestrian.

DESIGN TYPE: Timber superstructure on pile bents.

MATERIALS USED:

Longitudinal member: Seven timber beams, 12 by 22 inches per span.

Decking: Timber, 4 by 10 inches.

Abutments: Stone masonry.

Piers: Four piles (12-inch diameter) bent.

SPECIAL FEATURES: Used stapled connections rather than steel bolt.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Below United States standards, lower design loads.

QUALITY OF CONSTRUCTION AND MATERIALS: The design, details and arrangements of the bridge structure were below United States standards. Quality of material fair.

DAMAGE—EXTENT: None.

CAUSE: None.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: None.

Piers: None.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary: None.

Permanent: None.

REMARKS: Bridge being used but timber decking and railing in decayed condition.

PHOTOGRAPHS:

No.	*Direction and title*
37	Looking north at undamaged highway bridge over the Motoyasu-Gawa.

BRIDGE 19

Coordinates: 6G

Over River: Motoyasu-Gawa.

Distance from "Zero Point": Plan, 4,270; slant, 4,720.

USE: Highway and pedestrian.

DESIGN TYPE: Reinforced bents.

MATERIALS USED:

Longitudinal member: Seven reinforced-concrete beams, 13 by 20 inches per span.

Decking: Reinforced concrete with asphalt wearing surface.

Abutments: Concrete.

Piers: Concrete bents.

SPECIAL FEATURES: Longitudinal beams were haunched at supports. Concrete cap under beams only at every other pier.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Below United States standards, principally because of lower design loads.

QUALITY OF CONSTRUCTION AND MATERIALS: The design, details, and arrangements of the bridge structure were below United States standards. Quality of materials good.

DAMAGE—EXTENT: None.

CAUSE: None.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: All.

Piers: All.

Abutments. Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary: None.

Permanent: None.

REMARKS: Carrying an 18-inch water line along the north side supported on steel brackets and saddle along concrete bents.

PHOTOGRAPHS:

No.	*Direction and title*
38	Looking southeast at the north elevation of highway bridge over the Motoyasu-Gawa. Ornamental stone posts dislodged by blast.

BRIDGE 20

Coordinates: 6G

Over River: Motoyasu-Gawa.

Distance from "Zero Point": Plan, 2,900; slant, 3,450.

USE: Highway and pedestrian.

DESIGN TYPE: I-beam girders.

MATERIALS USED:

Longitudinal member: six by 20-inch I-beam with angle stiffeners.

Decking: Reinforced concrete with asphalt wearing surface.

Abutments: Stone.

MATERIALS USED—Continued

Piers: Four- by 12-inch H-column bents with 3- by 3- by 3/8-inch angles for diagonal bracing.

SPECIAL FEATURES: H-column of bents set in concrete footing.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Below United States standards because of lower design loads.

QUALITY OF CONSTRUCTION AND MATERIALS: The design, details, and arrangements of the bridge structure were below United States standards. Quality of material good for concrete.

DAMAGE — EXTENT: Superficial: No structural damage to girders. Very slight damage to railings. Very slight damage to steel bents.

CAUSE: Blast and flood.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: All.

Piers: All.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary: None.

Permanent: Replace broken concrete railings. Minor repairs to steel bents.

REMARKS: Sixteen-inch water main carried by brackets along steel bents.

PHOTOGRAPHS:

No.	*Direction and title*
39	Looking south at slight blast damage to northwest section of bridge over the Motoyasu-Gawa.
40	South elevation showing debris against bents deposited by flood.

BRIDGE 21

Coordinates: 5H

Over River: Motoyasu-Gawa.

Distance from "Zero Point": Plan, 1,450; slant, 2,460.

USE: Highway and pedestrian.

DESIGN TYPE: Timber superstructure on pile bents.

MATERIALS USED:

Longitudinal member: Twelve log girders, 10-inch per span.

Decking: Timber, 4 by 12 inches.

Abutments: Stone masonry.

Piers: Seven piles per bent (10-inch diameter).

SPECIAL FEATURES: Bridge skewed approximately 15°.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Not ascertainable.

QUALITY OF CONSTRUCTION AND MATERIALS: Not ascertainable.

DAMAGE—EXTENT: Complete destruction.

CAUSE: Spans at approximate bridge center initially damaged by blast, later totally destroyed by flood.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: All.

Piers: All.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary:

Permanent: New bridge required.

REMARKS: Constant replacement of piling required after floods.

PHOTOGRAPHS:

No.	Direction and title
42	Looking north at the southwest part of bridge over the Motoyasu-Gawa destroyed by blast and flood.

BRIDGE 22

Coordinates: 5H

Over River: Motoyasu-Gawa.

Distance from "Zero Point": Plan, 260; slant, 2,020.

USE: Highway and pedestrian.

DESIGN TYPE: Plate girder.

MATERIALS USED:

Longitudinal member: Thirty inches in depth.

Decking: Reinforced concrete with asphalt wearing surface.

Abutments: Concrete faced with masonry.

Piers: Concrete faced with masonry.

SPECIAL FEATURES: Girders haunched at supports.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: More massive. Generally, the bridges were designed to carry lower loadings than is American practice.

QUALITY OF CONSTRUCTION AND MATERIALS: The design, details and arrangements of the bridge were below United States standards. Quality of materials good for concrete and masonry.

DAMAGE—EXTENT: No structural damage to girders. Concrete railings completely destroyed. Ornamental posts dislodged.

CAUSE: Blast.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: All.

Piers: All.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary: None.

Permanent: Replace railings. Replace and reset ornamental posts. Resurface part of deck near abutments.

REMARKS: Nearest bridge to the zero point covered in the survey carrying a 16-inch water line.

PHOTOGRAPHS:

No.	Direction and title
43	Superficial blast damage to bridge over the Motoyasu-Gawa.
44	North elevation. No structural damage.
45	Stone posts and railings damaged by blast.
46	Blast effect on ornamental stone posts.

BRIDGE 23

Coordinates: 4H

Over River: Ota-Gawa.

Distance from "Zero Point": Plan, 860; slant, 2,170.

USE: Highway and pedestrian.

DESIGN TYPE: Plate girder.

MATERIALS USED:

Longitudinal member: Thirty-nine inches in depth.

Decking: Reinforced concrete with asphalt wearing surface.

Abutments: Concrete faced with stone masonry.

Piers: Concrete.

SPECIAL FEATURES: Girders haunched at supports. Girders abutting the south fact of Bridge 24 are cantilevered.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: More massive. Generally, the bridges were designed to carry lower loadings than is American practice.

QUALITY OF CONSTRUCTION AND MATERIALS: The design, details and arrangements of the bridge were below United States standards. Quality of materials good for concrete and masonry.

DAMAGE—EXTENT: Superficial. No structural damage to piers. Ornamental posts at south end of bridge slightly dislodged. Concrete railings along both sides of bridge completely destroyed.

CAUSE: Blast.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: All.

Piers: All.

Abutments: One. Note: only one abutment for this bridge.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary: No repairs necessary for temporary use.

Permanent: Replace concrete railings. Reset posts.

REMARKS: None.

PHOTOGRAPHS:

No.	*Direction and title*
47	Looking east at west elevation of Bridge 23. Note cantilever span to Bridge 24 over the Ota-Gawa.
48	Cast-iron post sections 5 feet on center for concrete railing sheared off east curb by blast.
49	Cast-iron post sections and concrete railing along west curb destroyed by blast.

BRIDGE 24

Coordinates: 4H

Over River: Ota-Gawa.

Distance from "Zero Point": Plan, 1,000; slant, 2,230.

USE: Highway, pedestrian and trolley.

DESIGN TYPE: Plate girder.

MATERIALS USED:

Longitudinal member: Forty-eight inches in depth.

Decking: Reinforced concrete with asphalt wearing surface.

Abutments: Concrete faced with stone masonry.

Piers: Concrete with stone masonry at corners.

SPECIAL FEATURES: Girders haunched at supports.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: More massive. Generally, the bridges were designed to carry lower loadings than is American practice.

QUALITY OF CONSTRUCTION AND MATERIALS: The design, details and arrangements of the bridge were below United States standards. Quality of materials good for concrete and masonry.

DAMAGE—EXTENT: Several main members slightly deflected. Concrete railings destroyed. Granite curbs and concrete walks partly destroyed. Concrete deck damaged. Trolley rails displaced at bridge ends. Ornamental stone posts of bridge damaged.

CAUSE: Blast.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: All.

Piers: All.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary: No repairs necessary for temporary service.

Permanent: Replace railings. Reset all power poles. Remove and replace all damaged walks, curbs, and roadway deck. Resurface part of deck.

REMARKS: Carried a double-track trolley line. The most used and outstanding bridge of the city of Hiroshima. It was the aiming point of the atomic bomb dropped at Hiroshima.

PHOTOGRAPHS:

No.	*Direction and title*
50	North elevation of bridge over Ota-Gawa. Concrete walk and railing damaged by blast.
51	Southeast part of bridge over Ota-Gawa. Railings damaged by blast.
52	Blast damage to southwest section. Concrete walk raised 20 inches above original road grade. Granite curbs moved 9½ inches south from original position.
53	North elevation adjacent to east abutment. No structural damage to plate girders.

PHOTOGRAPHS—Continued

No. *Direction and title*

54 Portion of north granite curb and walk. Drain scupper west of bridge 23 elevated 20 inches above road grade by blast effects.

55 Portion of north granite curb and walk. Drain scupper east of bridge 23 elevated 24 inches above road grade.

56 North concrete walk raised 38 inches above cross steel members, supporting the north walk, by blast effects.

57 Blast effects moved roadway slab laterally 15 inches north and raised it 14 inches above original position. Note pushed-up scupper.

58 Northwest corner of bridge showing blast damage to concrete walk, granite curb, and roadway concrete deck.

59 Northeast corner of bridge showing blast damage to concrete walk and granite curb.

60 Intersection of Bridge 23 and Bridge 24. Rails of south trolley tracks pushed up 8 inches above original road grade by blast.

61 Blast damage. Cast-iron post sections at northwest corner of intersection of Bridges 23 and 24. Post sections 5 feet on center for concrete railings of Bridge 23 and 6 feet on center for Bridge 24.

62 Northeast corner, steel-plate girder. No structural damage by blast.

63 Underside of steel plate girders and cross-members at east abutment. Slight defection.

64 Underside of steel-plate girders and cross-members at west abutment. No structural damage.

65 Secondary framing of exterior girder under north walk at approximate bridge center. No structural damage.

66 Inside faces of plate girders fourth span from east abutment under north walk. Deflected slightly by blast.

67 Inside faces of plate girders. Fifth span from east abutment under north walk. Deflected slightly by blast.

68 East end of bridge. Slight deflection in trolley rails due to shifting of bridge deck by blast.

PHOTOGRAPHS—Continued

No. *Direction and title*

69 West end of bridge. Trolley rails moved laterally 15 inches to the north as blast effect shifted bridge deck.

70 Intersection of Bridge 23 (left) and Bridge 24 (right). All damage from blast effects. Bridge 23 (860 feet to GZ, 2,170 feet to AZ). Bridge 24 (1,000 feet to GZ, 2,230 feet to AZ).

BRIDGE 25

Coordinates: 3H

Over River: Ota-Gawa.

Distance from "Zero Point": Plan, 5,200; slant, 5,570.

USE: Highway and pedestrian.

DESIGN TYPE: Reinforced concrete.

MATERIALS USED:

Longitudinal member: Seven reinforced-concrete beams, 13 by 24 inch per span.

Decking: Reinforced concrete (8 inches) asphaltic wearing surface.

Abutments: Concrete.

Piers: Concrete bents.

SPECIAL FEATURES: Some of the longitudinal beams were haunched at supports. Bridge is skewed.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: More massive. Generally, bridges were designed to carry lower loadings than is American practice.

QUALITY OF CONSTRUCTION AND MATERIALS: The design, details and arrangements of the bridge structure were below United States standards. Quality of materials good.

DAMAGE—EXTENT: Moderate to piers. Superficial to coping. One pier entirely destroyed and one pier partly damaged by flood. Deck over damaged piers also partly broken. Coping blown off by blast along both railings. Railing very slightly damaged by blast.

CAUSE: Flood.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: All.

Piers: All.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary: For heavy traffic loads, bents to be rebuilt and spans restored.

REPAIRS NECESSARY TO PLACE IN SERVICE—Continued

Permanent: Restore two spans and two bents. Also restore coping for railings and repair part of the railings.

REMARKS: Portion of two spans, continuous section unsupported for complete length. Bridge opened to light traffic.

PHOTOGRAPHS:

No.	*Direction and title*
71	Looking north at west elevation of bridge over Ota-Gawa. Flood damage. Superficial damage to concrete coping by blast.

BRIDGE 26

Coordinates: 3H

Over River: Ota-Gawa.

Distance from "Zero Point": Plan, 5,750; slant, 6,100.

USE: Railroad.

DESIGN TYPE: Plate girder.

MATERIALS USED:

Longitudinal member: Seventy-eight inches in depth.

Decking: Ties and rails.

Abutments: Concrete.

Piers: Concrete faced with brick.

SPECIAL FEATURES: Bridge skewed slightly.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Bridge would carry normal railroad loadings. Comparable with similar structures in United States.

QUALITY OF CONSTRUCTION AND MATERIALS: Comparable with similar structures in United States. Materials good for concrete and masonry.

DAMAGE—EXTENT: No structural damage to girders. Discoloring of old paint due to bomb effects along the south side of bridge. North face unaffected.

CAUSE: None.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: All.

Piers: All.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary: None.

Permanent: None.

REMARKS: Carries a double-track railroad.

PHOTOGRAPHS:

No.	*Direction and title*
72	South elevation of undamaged, double-track railroad bridge over Ota-Gawa.
73	Paint on the south elevation of girders discolored by exposure to bomb effects.
74	Paint on the north elevation of girders unaffected by bomb effects.

BRIDGE 27

Coordinates: 3G

Over River: Temma-Gawa.

Distance from "Zero Point": Plan, 4,360; slant, 4,790.

USE: Highway and pedestrian.

DESIGN TYPE: Steel arch.

MATERIALS USED:

Longitudinal member: Box chord. Top members of truss.

Decking: Reinforced concrete with asphalt wearing surface.

Abutments: Concrete.

Piers: None.

SPECIAL FEATURES: Tied arch at anchorage with 5- by 8-inch I-section vertical members. No diagonal bracing.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Below United States standards principally because of lower design loads.

QUALITY OF CONSTRUCTION AND MATERIALS: The design, details and arrangements of the bridge structure were below United States standards. Quality of materials good for masonry.

DAMAGE—EXTENT: None.

CAUSE: None.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: Entire single span.

Piers: None used.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary: None.

Permanent: None.

REMARKS: Carrying a 10-inch water main.

PHOTOGRAPHS:

No.	Direction and title
75	West elevation of bridge over the Temma-Gawa undamaged. Paint on the members of the east elevation were discolored by exposure to bomb effects. Steel members of the west elevation were slightly discolored.

BRIDGE 28

Coordinates: 3G

Over River: Temma-Gawa.

Distance from "Zero Point": Plan, 4,430; slant, 4,840.

USE: Highway, pedestrian and trolley.

DESIGN TYPE: Timber superstructure on pile bents.

MATERIALS USED:

Longitudinal member: Timber beams.

Decking: Timber.

Abutments: Concrete.

Piers: Timber pile bents.

SPECIAL FEATURES: None.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Not ascertainable.

QUALITY OF CONSTRUCTION AND MATERIALS: Not ascertainable.

DAMAGE—EXTENT: Complete destruction.

CAUSE: Flood.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: None.

Piers: None.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary:

Permanent: New bridge required.

REMARKS: Constant replacement of piling required after floods.

PHOTOGRAPHS:

No.	Direction and title
76	Looking north at remains of bridge at north abutment over the Temma-Gawa destroyed by flood.

BRIDGE 29

Coordinates: 5G

Over River: Ota-Gawa.

Distance from "Zero Point": Plan, 1,190; slant, 2,310.

USE: Highway and pedestrian.

DESIGN TYPE: Steel truss.

MATERIALS USED:

Longitudinal member: Box chord for top members of truss. Eye-bars for tension members.

Decking: Timber.

Abutments: Concrete faced with masonry.

Piers: Concrete faced with masonry.

SPECIAL FEATURES: Pin-connected steel truss of unusual design.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Below United States standards principally because of lower design loads.

QUALITY OF CONSTRUCTION AND MATERIALS: The design, details and arrangements of the bridge structure were below United States standard. Quality of materials fair for timber and good for masonry and concrete.

DAMAGE—EXTENT: Complete destruction.

CAUSE: Blast.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: None.

Piers: All.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary: Three new spans.

Permanent: New bridge required with the exception of piers and abutment.

REMARKS: Carries 16-inch water main.

PHOTOGRAPHS:

No.	Direction and title
77	Looking north at remains of bridge over the Ota-Gawa. Destroyed by blast.
78	Looking northeast at southwest corner, destroyed by blast.
79	Looking south at east abutment. Bridge destroyed by blast.
80	Looking east at debris of bridge structure at west abutment. Bridge destroyed by blast.

BRIDGE 30

Coordinates: 5G

Over River: Ota-Gawa.

Distance from "Zero Point": Plan, 1,930; slant, 2,800.

USE: Highway and pedestrian.

DESIGN TYPE: Reinforced concrete.

MATERIALS USED:

Longitudinal member: Seven reinforced-concrete beams, 12 by 36 inch per span.

Decking: Reinforced concrete (6-inch) with asphalt wearing surface.

Abutments: Concrete.

Piers: Concrete bents.

SPECIAL FEATURES: Longitudinal beams were haunched at supports.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Below United States standards principally because of lower design loads.

QUALITY OF CONSTRUCTION AND MATERIALS: The design, details, and arrangements of the bridge structure were below United States standards. Quality of material good.

DAMAGE — EXTENT: Severe. Four center spans destroyed and second span from west end being held by reinforcing steel, at pier adjacent to west abutment. Major portion of railing destroyed.

CAUSE: Flood.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: Two spans near east end and one span near west end.

Piers: Two bents near east end and one pier near west end.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary: Rebuild four spans and three bents between existing structures.

Permanent: Restore four spans and three concrete bents, also replace railings.

REMARKS: Nearest reinforced-concrete bridge to the zero point.

PHOTOGRAPHS:

No.	Direction and title
81	Looking north at flood-damaged highway bridge over the Ota-Gawa.
82	Roadway deck and girder reinforcing steel.
83	Steel reinforcement in concrete girder.
84	Roadway deck and girder, reinforcing steel.

BRIDGE 30A

Coordinates: 5G

Over River: Ota-Gawa.

Distance from "Zero Point": Plan, 1,880; slant, 2,750.

USE: Water crossing.

DESIGN TYPE: Steel truss.

MATERIALS USED:

Longitudinal member: 3- by 3- by $\frac{3}{8}$-inch angles.

Decking: 2- by 2- by $\frac{1}{4}$-inch angles, $\frac{1}{4}$- by 2-inch bars comprising the steel bracing.

Abutments: Stone masonry.

Piers: Concrete.

SPECIAL FEATURES: Bow truss.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Bridge would carry normal aqueduct loadings. Comparable with similar structures in United States.

QUALITY OF CONSTRUCTION AND MATERIALS: Comparable with similar structures in United States. Materials good for concrete and masonry.

DAMAGE—EXTENT: Slight. Steel members of truss slightly deformed.

CAUSE: Blast.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: All.

Piers: All.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary: None.

Permanent: None.

REMARKS:

Aqueduct, carrying a 16-inch water line.

PHOTOGRAPHS:

No.	Direction and title
85	North elevation of bridge over the Ota-Gawa slightly damaged by blast. Aqueduct carrying a 16-inch water main.
86	Looking northeast at corner of west abutment. Steel truss members slightly damaged by blast. Note damaged covering of 16-inch water main.

BRIDGE 31

Coordinates: 6G

Over River: Ota-Gawa.

Distance from "Zero Point": Plan, 4,570; slant, 5,000.

USE: Highway and pedestrian.

DESIGN TYPE: Reinforced concrete.

MATERIALS USED:

Longitudinal member: Seven reinforced-concrete beams, 16 by 20 inch per span.

Decking: Reinforced concrete with asphalt wearing surface.

Abutments: Concrete.

Piers: Concrete bents.

SPECIAL FEATURES: Longitudinal beams were haunched at support.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Below United States standards principally because of lower design loads.

QUALITY OF CONSTRUCTION AND MATERIALS: The design, details and arrangements of the bridge structure were below United States standards. Quality of materials good.

DAMAGE—EXTENT: Severe. All spans destroyed except one on east end and four spans on the west end of bridge. Railing, also, partly destroyed.

CAUSE: Flood.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: Four near west end and one span near east end.

Piers: Five concrete bents.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary: Rebuild seven spans and six bents.

Permanent: Restore seven concrete spans and six concrete bents; also, replace railings.

REMARKS: Carrying 16-inch water main along the north side by bents.

PHOTOGRAPHS:

No.	*Direction and title*
87	Looking south at flood-damaged highway bridge over the Ota-Gawa. Top portion of the northwest corner post dislodged by blast.

BRIDGE 32

Coordinates: 7E, F

Over River: Temma-Gawa.

Distance from "Zero Point": Plan, 9,400; slant, 9,600.

USE: Highway and pedestrian.

DESIGN TYPE: Timber superstructure on pile bents.

MATERIALS USED:

Longitudinal member: Seven log beams (12-inch diameter) per span.

Decking: Four-inch logs.

Abutments: Stone masonry.

Piers: Five piles, 12-inch diameter per bent.

SPECIAL FEATURES: Unusual deck construction. More diagonal bracing than ordinary.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Below United States standards, lower design loads.

QUALITY OF CONSTRUCTION AND MATERIALS: The design, details and arrangements of the bridge structure were below United States standards. Quality of material fair.

DAMAGE—EXTENT: Severe.

CAUSE: The center portion of bridge severely damaged by flood.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: Approximately 16.

Piers: Approximately 16.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary: Replace 15 bents and 16 spans.

Permanent: Replace 15 bents and 16 spans.

REMARKS: Constant replacement of piling required after floods.

PHOTOGRAPHS:

No.	*Direction and title*
88	Looking north at flood damaged highway bridge over the Temma-Gawa.

BRIDGE 33

Coordinates: 6F

Over River: Temma-Gawa.

Distance from "Zero Point": Plan, 5,300; slant, 5,650.

USE: Highway and pedestrian.

DESIGN TYPE: Reinforced concrete.

MATERIALS USED:

Longitudinal member: Five reinforced-concrete beams, 13 by 18 inch per span.

Decking: Reinforced concrete with asphalt wearing surface.

Abutments: Concrete.

Piers: Concrete bents.

SPECIAL FEATURES: Longitudinal beams were haunched at supports.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Below United States standards, principally because of lower design loads.

QUALITY OF CONSTRUCTION AND MATERIALS: The design, details, and arrangements of the bridge structure were below United States standards. Quality of materials good.

DAMAGE—EXTENT: Severe. Eight spans and seven concrete bents completely destroyed.

CAUSE: Flood.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: Four adjacent to west abutment.

Piers: Three concrete bents.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary: Rebuild eight spans and seven bents.

Permanent: Restore eight concrete spans and seven concrete bents; also, replace railings.

REMARKS: Carrying 16-inch water main by bents.

PHOTOGRAPHS:

No.	*Direction and title*
89	Looking west at flood damaged bridge over the Temma-Gawa.

BRIDGE 34

Coordinates: 5G

Over River: Temma-Gawa.

Distance from "Zero Point": Plan, 3,700; slant, 4,200.

USE: Highway and pedestrian.

DESIGN TYPE: Timber superstructure on pile bents.

MATERIALS USED:

Longitudinal member: Timber beam.

Decking: Timber.

Abutments: Stone masonry.

Piers: Four piles per bent.

SPECIAL FEATURES: None.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Not ascertainable.

QUALITY OF CONSTRUCTION AND MATERIALS: Not ascertainable.

DAMAGE—EXTENT: Complete destruction.

CAUSE: Spreading of fires from adjacent buildings.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: None.

Piers: None.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary:

Permanent: New bridge required.

REMARKS: Constant replacement of piling after floods.

PHOTOGRAPHS:

No.	*Direction and title*
90	Looking west at timber bridge over the Temma-Gawa, completely destroyed by fire.

BRIDGE 35

Coordinates: 5G

Over River: Temma-Gawa.

Distance from "Zero Point": Plan, 3,190; slant, 3,750.

USE: Trolley (double track).

DESIGN TYPE: I-beam girder.

MATERIALS USED:

Longitudinal member: I-beam (24-inch) with angle stiffeners.

Decking: Ties and rails.

Abutments: Stone.

Piers: H-column bents with diagonal bracing.

SPECIAL FEATURES: Steel H-column poles carrying trolley overhead electric system.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Below United States standards; lower design loads.

QUALITY OF CONSTRUCTION AND MATERIALS: The design, details and arrangements of the bridge structure were below United States standards. Quality of material fair for timber.

DAMAGE—EXTENT: Complete destruction.

CAUSE: Flood.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: None.

Piers: None.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary:

Permanent: New bridge required.

REMARKS: Carried a double-track trolley line.

PHOTOGRAPHS:

No.	Direction and title
98	Looking north at remains of bridge (at east abutment) over the Temma-Gawa, completely destroyed by flood.
92	Looking west at remains of trolley bridge (at west abutment) destroyed by flood.

BRIDGE 36

Coordinates: 5G

Over River: Temma-Gawa.
Distance from "Zero Point": Plan, 3,200; slant, 3,760.
USE: Pedestrian.
DESIGN TYPE: Timber superstructure on pile bents.
MATERIALS USED:
- Longitudinal member: Five log beams (12-inch diameter) per span.
- Decking: Timber, 2 by 6 inches.
- Abutments: Stone masonry.
- Piers: Three pile (12-inch diameter) bents.

SPECIAL FEATURES: None.
HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Not ascertainable.
QUALITY OF CONSTRUCTION AND MATERIALS: Not ascertainable.
DAMAGE—EXTENT: Complete destruction.
CAUSE: Flood.
REPAIR AND SALVAGE:
EXTENT USABLE:
- Spans: None.
- Piers: None.
- Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:
- Temporary:
- Permanent: New bridge required.

REMARKS: Constant replacement of piling required after floods.
PHOTOGRAPHS:

No.	Direction and title
93	Looking west at remains of bridge (east and west abutments) over the Temma-Gawa, completely destroyed by flood.

BRIDGE 37

Coordinates: 5G

Over River: Temma-Gawa.
Distance from "Zero Point": Plan, 3,220; slant, 3,770.
USE: Highway and pedestrian.
DESIGN TYPE: Plate girder.
MATERIALS USED:
- Longitudinal member: Fifty inches in depth.
- Decking: Timber, 4 by 12 inches.
- Abutments: Concrete.
- Piers: Concrete.

SPECIAL FEATURES: Fourteen-inch water main carried by brackets along the south side.
HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Below United States standards; lower design loads.
QUALITY OF CONSTRUCTION AND MATERIALS: The design, details, and arrangements of the bridge structure were below United States standards. Quality of material fair for wood.
DAMAGE—EXTENT: Severe. Two spans and one pier completely destroyed, adjacent to west abutment.
CAUSE: Flood.
REPAIR AND SALVAGE:
EXTENT USABLE:
- Spans: Two.
- Piers: Two.
- Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:
- Temporary: One pier and two spans.
- Permanent: One pier and two spans.

REMARKS: Destroyed spans being replaced by timber construction to permit immediate use of the bridge.
PHOTOGRAPHS:

No.	Direction and title
94	Looking north at plate girder, timber-decked highway bridge over the Temma-Gawa. Westerly portion severely damaged by flood. Fourteen-inch water main carried by brackets along the south side.

BRIDGE 38

Coordinates: 4G

Over River: Temma-Gawa.
Distance from "Zero Point": Plan, 3,750; slant, 4,250.
USE: Highway and pedestrian.
DESIGN TYPE: Timber superstructure on pile bents.

MATERIALS USED:
Longitudinal member: Timber beams.
Decking: Timber.
Abutments: Stone masonry.
Piers: Four piles (10-inch diameter) per bent.

SPECIAL FEATURES: None.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Not ascertainable.

QUALITY OF CONSTRUCTION AND MATERIALS: Not ascertainable.

DAMAGE—EXTENT: Complete destruction.

CAUSE: Westerly half severely damaged by fire, later completely destroyed by flood.

REPAIR AND SALVAGE:

EXTENT USABLE:
Spans: None.
Piers: None.
Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:
Temporary:
Permanent: New bridge required.

REMARKS: Constant replacement of piling required after floods.

PHOTOGRAPHS:

No.	*Direction and title*
95	Looking west at remains of timber bridge over the Temma-Gawa severely damaged by fire (west half) and completely destroyed by flood.

BRIDGE 39

Coordinates: 4G

Over River: Temma-Gawa.

Distance from "Zero Point": Plan, 3,880; slant, 4,390.

USE: Highway and pedestrian.

DESIGN TYPE: Timber superstructure on pile bents.

MATERIALS USED:
Longitudinal member: Seven timber beams, 6- by 14-inch, per span.
Decking: Timber, 2 by 10 inches.
Abutments: Stone masonry.
Piers: Four piles per bent.

SPECIAL FEATURES: None.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Not ascertainable.

QUALITY OF CONSTRUCTION AND MATERIALS: Not ascertainable.

DAMAGE—EXTENT: Complete destruction.

CAUSE: Easterly third severely damaged by fire, later completely destroyed by flood.

REPAIR AND SALVAGE:

EXTENT USABLE:
Spans: None.
Piers: None.
Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:
Temporary:
Permanent: New bridge required.

REMARKS: Constant replacement of piling, required after floods.

PHOTOGRAPHS:

No.	*Direction and title*
96	Looking northwest at remains of timber bridge over the Temma-Gawa severely damaged by fire, easterly one-third and completely destroyed by flood.

BRIDGE 40

Coordinates: 3G

Over River: Fukushima-Gawa.

Distance from "Zero Point": Plan, 5,360; slant, 5,700.

USE: Highway and pedestrian.

DESIGN TYPE: Timber superstructure on pile bents.

MATERIALS USED:
Longitudinal member: Seven timber beams, 6 by 14 inch per span.
Decking: Timber, 2 by 10 inches.
Abutments: Concrete.
Piers: Four piles, 10-inch diameter per bent.

SPECIAL FEATURES: Used stapled connections rather than steel bolt.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Below United States standards; lower design loads.

QUALITY OF CONSTRUCTION AND MATERIALS: The design, details and arrangements of the bridge structure were below United States standards. Quality of material fair.

DAMAGE—EXTENT: Severe.

CAUSE: The northerly portion of bridge severely damaged by fire.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: Eight (southerly portion of bridge).

Piers: Eight (southerly portion of bridge).

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary: Replace 10 spans and 9 bents.

Permanent: Replace 11 spans 10 bents.

REMARKS: Constant replacement of piling required after floods.

PHOTOGRAPHS:

No.	Direction and title
97	Looking at bridge over the Fukushima-Gawa, northerly portion severely damaged by fire.

BRIDGE 41

Coordinates: 3F

Over River: Between Yamate-Gawa and Fukushima-Gawa.

Distance from "Zero Point": Plan, 6,150; slant, 6,460.

USE: Highway and pedestrian.

DESIGN TYPE: Reinforced concrete.

MATERIALS USED:

Longitudinal member: Four reinforced-concrete beams, 12 by 14 inch per span.

Decking: Reinforced concrete (8-inch).

Abutments: Concrete.

Piers: Concrete bents.

SPECIAL FEATURES: Longitudinal beams were haunched. Simply supported.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Below United States standards principally because of lower design loads.

QUALITY OF CONSTRUCTION AND MATERIALS: The design, details and arrangements of the bridge structure were below United States standards. Quality of materials good.

DAMAGE—EXTENT: None.

CAUSE: None.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: All.

Piers: All.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary: None.

Permanent: None.

REMARKS: Structure well protected from blast.

PHOTOGRAPHS:

No.	Direction and title
98	Looking west at undamaged concrete bridge between the Yamate Gawa and the Fukushima Gawa.

BRIDGE 42

Coordinates: 4F

Over River: Fukushima-Gawa.

Distance from "Zero Point": Plan, 5,100; slant, 5,490.

USE: Highway and pedestrian.

DESIGN TYPE: Timber superstructure on pile bents.

MATERIALS USED:

Longitudinal member: Timber beams.

Decking: Timber, 2 by 6 inches.

Abutments: Stone masonry and timber.

Piers: Four piles (10-inch diameter) per bent.

SPECIAL FEATURES: None.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Below United States standards; lower design loads.

QUALITY OF CONSTRUCTION AND MATERIALS: The design, details and arrangements of the bridge structure were below United States standards. Quality of materials fair.

DAMAGE—EXTENT: Complete destruction.

CAUSE: Bridge completely destroyed by flood with the exception of one span near the west abutment and two bents.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: One.

Piers: Two.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary: Replace 13 spans and 13 bents.

Permanent: New bridge required.

REMARKS: Constant replacement of piling required after floods.

PHOTOGRAPHS:

No.	Direction and title
99	Looking west at remains of timber bridge (east and west abutments) over the Fukushima-Gawa destroyed by flood.

BRIDGE 43

Coordinates: 4F

Over River: Fukushima-Gawa.

Distance from "Zero Point": Plant, 5,180; slant, 5,510.
USE: Highway and pedestrian.
DESIGN TYPE: Timber superstructure on pile bents.
MATERIALS USED:
Longitudinal member: Timber logs 4 per span.
Decking: Timber.
Abutments: Stone masonry.
Piers: Four piers per bent.
SPECIAL FEATURES: None.
HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Not ascertainable.
QUALITY OF CONSTRUCTION AND MATERIALS: Not ascertainable.
DAMAGE—EXTENT: Complete destruction.
CAUSE: The two mid-spans initially damaged by blast, later completely destroyed by fire which spread to adjacent buildings.
REPAIR AND SALVAGE:
EXTENT USABLE:
Spans: None.
Piers: None.
Abutments: Both.
REPAIRS NECESSARY TO PLACE IN SERVICE:
Temporary:
Permanent: New bridge required.
REMARKS: A new timber bridge was erected for urgent use immediately after blast and fire damage.
PHOTOGRAPHS:

No.	*Direction and title*
100	Looking south at north elevation of newly constructed timber bridge over the Fukushima-Gawa. Old bridge was destroyed by blast and fire.

BRIDGE 44

Coordinates: 4F and 5F

Over River: Fukushima-Gawa.
Distance from "Zero Point": Plan, 5,300; slant, 5,650.
USE: Trolley.
DESIGN TYPE: I-beam girder.
MATERIALS USED:
Longitudinal member: I-beam 24-inch with angle stiffeners.
Decking: Ties and trolley rails.
Abutments: Stone.

MATERIALS USED—Continued
Piers: Four H columns per bent with diagonal bracing. H columns set in concrete.
SPECIAL FEATURES: Steel, H-column, electric poles carrying trolley overhead system.
HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Below United States standards; lower design loads.
QUALITY OF CONSTRUCTION AND MATERIALS: The design, details and arrangements of the bridge structure were below United States standards. Quality of material fair for timber.
DAMAGE—EXTENT: None.
CAUSE: None.
REPAIR AND SALVAGE:
EXTENT USABLE:
Spans: All.
Piers: All.
Abutments: Both.
REPAIRS NECESSARY TO PLACE IN SERVICE:
Temporary: None.
Permanent: None.
REMARKS: Carrying a double-track trolley line.
PHOTOGRAPHS:

No.	*Direction and title*
101	Looking northwest at the southeast area of undamaged trolley bridge over the Fukushima-Gawa.

BRIDGE 45

Coordinates: 5E

Over River: Fukushima-Gawa.
Distance from "Zero Point": Plan, 7,010; slant, 7,300.
USE: Highway and pedestrian.
DESIGN TYPE: Reinforced concrete.
MATERIALS USED:
Longitudinal member: Five reinforced-concrete beams, 13 by 18 inch per span.
Decking: Reinforced concrete (8-inch) with asphalt wearing surface.
Abutments: Concrete.
Piers: Concrete bents.
SPECIAL FEATURES: Longitudinal beams were haunched at supports.
HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Below United States standards principally because of lower design loads.

QUALITY OF CONSTRUCTION AND MATERIALS: The design, details and arrangements of the bridge structure were below United States standards. Quality of materials good.

DAMAGE—EXTENT: Moderate. Two concrete spans and two concrete bents near east abutment partly damaged due to settlement. Railing also partly damaged at the southeast and northeast corners.

CAUSE: Flood.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: All.

Piers: All.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary: None.

Permanent: Restore two concrete spans and bents. Also replace damaged railings.

REMARKS: Bridge opened to light traffic.

PHOTOGRAPHS:

No.	*Direction and title*
102	Looking northwest at the southeast area of concrete highway bridge over the Fukushima-Gawa moderately damaged by flood.

BRIDGE 46

Coordinates: 5E

Over River: Yamate-Gawa.

Distance from "Zero Point": Plan, 8,090; slant, 8,350.

USE: Highway and pedestrian.

DESIGN TYPE: Timber superstructure on pile bents.

MATERIALS USED:

Longitudinal member: Timber beams.

.Decking: Timber.

Abutments: Stone masonry.

Piers: Four piles per bent.

SPECIAL FEATURES: None.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Not ascertainable.

QUALITY OF CONSTRUCTION AND MATERIALS: Not ascertainable.

DAMAGE—EXTENT: Complete destruction.

CAUSE: Flood.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: None.

Piers: None.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary:

Permanent: New bridge required.

REMARKS: Constant replacement of piling required after floods.

PHOTOGRAPHS:

No.	*Direction and title*
103	Looking west at remains of timber bridge over the Yamate-Gawa completely destroyed by flood.

BRIDGE 47

Coordinates: 4E

Over River: Yamate-Gawa.

Distance from "Zero Point": Plan, 7,450; slant, 7,700.

USE: Trolley.

DESIGN TYPE: I-beam girder.

MATERIALS USED:

Longitudinal member: I-beam 24 inch with angle stiffeners.

Decking: Ties and trolley rails.

Abutments: Stone and concrete.

Piers: Four H-columns per bent with diagonal bracing. H-columns set in concrete.

SPECIAL FEATURES: Steel H-column, electric poles carrying trolley overhead system.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Below United States standards; lower design loads.

QUALITY OF CONSTRUCTION AND MATERIALS: The design, details and arrangements of the bridge structure were below United States standards. Quality of material fair for timber.

DAMAGE—EXTENT: None.

CAUSE: None.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: All.

Piers: All.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary: None.

Permanent: None.

REMARKS: Furthermost trolley bridge from the zero point. Carrying double-track trolley line.

PHOTOGRAPHS:

No.	Direction and title
104	Looking at undamaged trolley bridge over the Yamate-Gawa.

BRIDGE 48

Coordinates: 4E

Over River: Yamate-Gawa.

Distance from "Zero Point": Plan, 7,130; slant, 7,400.

USE: Highway and pedestrian.

DESIGN TYPE: Plate girder.

MATERIALS USED:

Longitudinal member: 42 inches in depth.

Decking: Reinforced concrete with asphalt wearing surface.

Abutments: Concrete.

Piers: Concrete with stone facing at croners.

SPECIAL FEATURES: Girders not haunched.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: More massive. Generally, the bridges were designed to carry lower loadings than is American practice.

QUALITY OF CONSTRUCTION AND MATERIALS: The design, details and arrangements of the bridge were below United States standards. Quality of materials good for concrete and masonry.

DAMAGE—EXTENT: None.

CAUSE: None.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: All.

Piers: All.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary: None.

Permanent: None.

REMARKS: Carrying 12- and 14-inch water mains.

PHOTOGRAPHS:

No.	Direction and title
105	Looking north. Showing the south elevation.

BRIDGE 49

Coordinates: 3F

Over River: Yamate-Gawa.

Distance from "Zero Point": Plan, 6,380; slant, 6,650.

USE: Pedestrian.

DESIGN TYPE: Timber superstructure on bents.

MATERIALS USED:

Longitudinal member:

Decking: Timber.

Abutments: Stone masonry.

Piers: Two piles per bent.

SPECIAL FEATURES: None.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Not ascertainable.

QUALITY OF CONSTRUCTION AND MATERIALS: Not ascertainable.

DAMAGE—EXTENT: Complete destruction.

CAUSE: Flood.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: None.

Piers: None.

Abutments: None.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary:

Permanent: New bridge required.

REMARKS: Constant replacement of piling required after floods.

PHOTOGRAPHS:

No.	Direction and title
106	Looking northwest at remains of timber foot bridge over the Yamate-Gawa destroyed by flood.

BRIDGE 50

Coordinates: 3G

Over River: Yamate-Gawa.

Distance from "Zero Point": Plan, 6,580; slant, 6,900.

USE: Railroad.

DESIGN TYPE: Plate girder.

MATERIALS USED:

Longitudinal member: Forty-nine inches in depth.

Decking: Ties and rails.

Abutments: Concrete.

Piers: Concrete faced with brick masonry at corners.

SPECIAL FEATURES: Skewed approximately 45°.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Bridge would carry normal railroad loadings. Comparable with similar structures in United States.

QUALITY OF CONSTRUCTION AND MATERIALS: Comparable with similar structures in United States. Materials good for concrete and masonry.

DAMAGE—EXTENT: No structural damage to girders, only discoloring of old paint along the south face of bridge. North face unaffected.

CAUSE: Bomb effects.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: All.

Piers: All.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary: None.

Permanent: None.

REMARKS: Carrying a double-track railroad line.

PHOTOGRAPHS:

No.	Direction and title
107	South elevation. Undamaged plate-girder, railroad bridge over the Yamate-Gawa. Paint of girders on the south elevation slightly discolored by exposure to bomb effects. North elevation unaffected by bomb effects.

BRIDGE 51

Coordinates: 3G

Over River: Underpass.

Distance from "Zero Point": Plan, 6,450; slant, 6,780.

USE: Railroad.

DESIGN TYPE: Plate girder.

MATERIALS USED:

Longitudinal member: Forty-eight and 36 inches in depth.

Decking: Ties and rails.

Abutments: Concrete.

Piers: Concrete.

SPECIAL FEATURES: Skewed approximately 45°.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Bridges would carry normal railroad loads. Comparable with similar structures in United States.

QUALITY OF CONSTRUCTION AND MATERIALS: Comparable with similar structures in United States. Materials good for concrete and masonry.

DAMAGE—EXTENT: No structural damage to girders. Only discoloring of old paint due to bomb effects along the south face of bridge. North face unaffected.

CAUSE: Bomb effects.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: All.

Piers: All.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary: None.

Permanent: None.

REMARKS: Carrying a double-track railroad line.

PHOTOGRAPHS:

No.	Direction and title
108	South elevation. Undamaged, plate-girder, railroad bridge and underpass. Paint of girders on the south elevation slightly discolored by exposures to bomb effects. North elevation unaffected by bomb effects.
109	Showing printed information on the face of the north plate girder at east abutment, Cooper E–40 loading.

BRIDGE 52

Coordinates: 8J

Over River: Creek.

Distance from "Zero Point": Plan, 12,200; slant, 12,450.

USE: Highway and pedestrian.

DESIGN TYPE: Reinforced concrete.

MATERIALS USED:

Longitudinal member: Three reinforced-concrete beams, 13 by 21 inch per span.

Decking: Seven-inch reinforced concrete.

Abutments: Concrete.

Piers: Concrete.

SPECIAL FEATURES: Longitudinal beams were haunched at support with cantilever spans at center of bridge.

HOW DOES STRENGTH COMPARE WITH UNITED STATES BRIDGES: Below United States standards principally because of lower design loads.

QUALITY OF CONSTRUCTION AND MATERIALS: The design, details, and arrangements of the bridge structure were below United States standards. Quality of materials good.

DAMAGE—EXTENT: None.

CAUSE: None.

REPAIR AND SALVAGE:

EXTENT USABLE:

Spans: All.

Piers: All.

Abutments: Both.

REPAIRS NECESSARY TO PLACE IN SERVICE:

Temporary: None.

Permanent: None.

REMARKS: Furthermost bridge from the zero point.

PHOTOGRAPHS:

No.	*Direction and title*
110	General oblique view showing most remote bridge included in study, 12,200 feet to GZ, 12,450 feet to AZ.

SECTION XIII

DAMAGE TO SERVICES AND UTILITIES

A. CITY ELECTRIC RAILWAY AND BUS SYSTEM

1. Summary

a. Traffic. Hiroshima, a city of approximately 245,000 persons, depended almost entirely upon the Hiroshima Electric Railway Co., Inc., for transportation within the city itself and to the outlying districts, including the resort town of Miyajima, about 10 miles to the southwest. The greatest recorded passenger traffic per month was 4,200,000 persons within the city and 800,000 persons using the Miyajima line during July 1945.

b. Equipment. The Sendamachi station, with the main offices, converter station, and warehouses and repair units within the station area was the base of operations. The Yagurashita converter station was situated in another part of town and divided the power output required to operate the system. Figure 1 shows the location of the stations and the extent of the railway system. Both stations, Sendamachi and Yagurashita, received electrical power from the Chugoku Electric Co., of Hiroshima, at 22 kilowatts AC, transforming and converting the alternating current to 600 volts DC, which was the operating voltage.

c. Street Railway Cars. The railway company operated 123 cars, the largest of which weighed 18 tons empty and 26 tons loaded, and was rated at 37.3 kilowatts. An overhead system provided electric power to the cars for operation.

d. Transmission System. The overhead system was supported by wood, steel, and concrete poles, and a single copper conductor per pair of rails provided the electric power for the street railway cars. The entire 15.5 miles of the system within the city were double track, as were 6 of the 10 miles of the Miyajima section. The rails were of United States and Japanese manufacture, having a gauge of 4 feet 8.5 inches, set on 8-inch ties 7 feet long.

e. Bridges. Because of the delta formation of the city, 8 bridges constructed of timber and steel were required to complete the track system.

f. Buses. The company employed 85 buses to serve areas not reached by street cars. Since gasoline was so scarce, buses were driven on a gaseous fuel which was produced by a unit carried on each bus as a part of the equipment.

g. Damage to Buildings. The atomic bomb exploded at 2,000 feet above ground zero (GZ) which is indicated on Figure 1. Primary blast damage put the whole transportation system out of service. Buildings and equipment at Sendamachi and Yagurashita, 6,700 and 900 feet distant from GZ, respectively, were damaged sufficiently to be inoperative. The extent of damage to buildings and equipment is indicated on Table 1. Fires that followed completed the destruction at Yagurashita, but the existence of a firebreak north of Sendamachi prevented the ignition of its buildings. The converting equipment at Sandamachi was repaired by 9 August 1945.

h. MAE for Buildings. The buildings pertinent to this report, including installations and equipment (Table 1), are classified by the building damage section of this report. Any conclusions for the mean areas of effectiveness (MAE) contained in that section will apply also for buildings in this section.

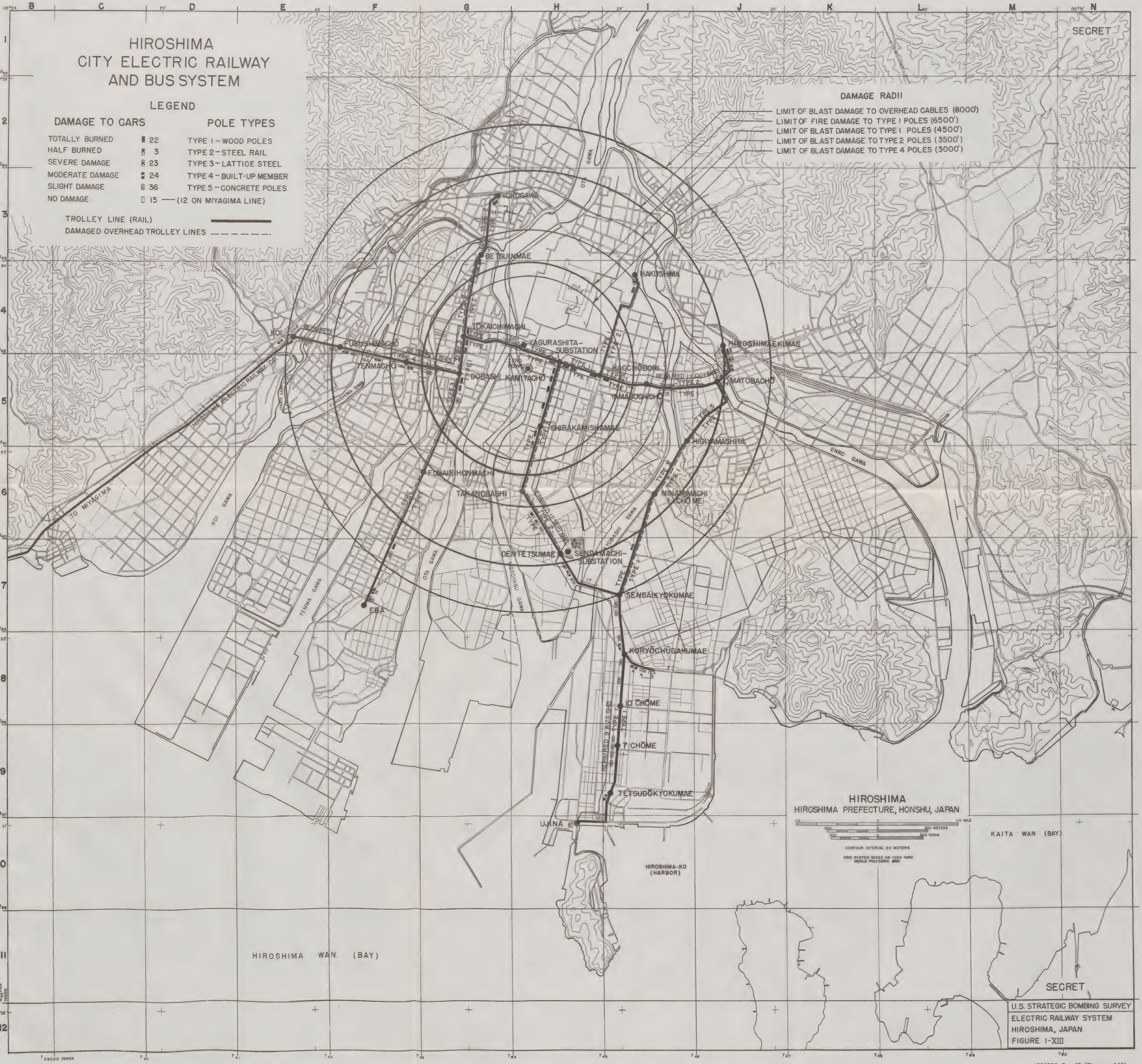
i. Damage to Rolling Stock. Of the 123 cars operated by the company, 25 were damaged by fire and 56 by blast. Of the 85 motor buses, 18 were damaged by fire and 22 by blast. Cars and buses within a radius of 1,500 feet of GZ were ignited by radiant heat. Because of the nonuniform distribution of the cars and buses no attempt has been made to calculate MAE's. Maximum and minimum radii for total, heavy, and slight damage, however, have been drawn graphically on Figure 4.

j. Damage to Overhead System. Blast and fire damaged 11.4 miles of the overhead transmission system which included 500 wood and 100 steel poles. No damage occurred to concrete poles, the nearest of which were 6,000 feet from GZ. Wood poles were damaged at a maximum distance of 4,500 feet from GZ, and steel poles, 3,500 feet. Overhead transmission cable was blown down by blast at 8,000 feet from GZ. The steel-rail pole (Type 2, Fig. 3) or its equivalent seemed best suited to support an overhead transmission system for street railway transportation, rather than wood or latticed-steel poles, as a protective measure against an attack of this type.

k. Damage to Bridges. With the exception of the bridge crossings (Table 5), no damage occurred to the track system. Since the bridges referred to in this section are covered by the Bridge Damage Section, all data in connection with damage to bridge crossings will be found in Section XII of this report.

2. The System

a. The locations of all buildings, substations, and overhead systems of the Hiroshima Electric Railway Co., Inc., are indicated on Figures 1 and



HIROSHIMA
CITY ELECTRIC RAILWAY
AND BUS SYSTEM
LEGEND
DAMAGE TO CARS
TOTALLY BURNED 22
HALF BURNED 3
SEVERE DAMAGE 23
MODERATE DAMAGE 24
SLIGHT DAMAGE 36
NO DAMAGE 15 —(12 ON MIYAGIMA LINE)
POLE TYPES
TYPE 1 – WOOD POLES
TYPE 2 – STEEL RAIL
TYPE 3 – LATTICE STEEL
TYPE 4 – BUILT-UP MEMBER
TYPE 5 – CONCRETE POLES
TROLLEY LINE (RAIL)
DAMAGED OVERHEAD TROLLEY LINES
SECRET
DAMAGE RADII
LIMIT OF BLAST DAMAGE TO OVERHEAD CABLES (8000')
LIMIT OF FIRE DAMAGE TO TYPE 1 POLES (6500')
LIMIT OF BLAST DAMAGE TO TYPE 1 POLES (4500')
LIMIT OF BLAST DAMAGE TO TYPE 2 POLES (3500')
LIMIT OF BLAST DAMAGE TO TYPE 4 POLES (3000')
YOKOGAWA
BETSUINMAE
HAKUSHIMA
TOKAICHIMACHI
YAGURASHITA-SUBSTATION
HACCHOBORI
HIROSHIMAEKIMAE
MATOBACHO
YAMAGUCHICHO
FUKUSHIMACHO
TENMACHO
DOBASHI
KAMIYACHO
KOI
REPAIRED
HIROSHIMA ELECTRIC RAILWAY CO.
TO MIYAGIMA
SHIRAKAMISHAMAE
HIGIYAMASHITA
ENKO GAWA
FUNAIRIHONMACHI
TAKANOBASHI
MINAMIMACHI 1 CHOME
DENTETSUMAE
SENDAMACHI-SUBSTATION
SENBAIKYOKUMAE
EBA
KOI GAWA
TEMMA GAWA
OTA GAWA
KYOBASHI GAWA
OTA GAWA
KORYOCHUGAKUMAE
10 CHOME
7 CHOME
TETSUDOKYOKUMAE
UJINA
REPAIRED 2 AUG 1945
HIROSHIMA-KO (HARBOR)
HIROSHIMA WAN (BAY)
KAITA WAN (BAY)
HIROSHIMA
HIROSHIMA PREFECTURE, HONSHU, JAPAN
CONTOUR INTERVAL 20 METERS
GRID SYSTEM BASED ON 1000 YARD WORLD POLYCONIC GRID
SECRET
U.S. STRATEGIC BOMBING SURVEY
ELECTRIC RAILWAY SYSTEM
HIROSHIMA, JAPAN
FIGURE I-XIII

2. With the exception of the areas noted on figure 1, the company served the entire city with street railway transportation, including a connection to Miyajima, a resort approximately 10 miles southwest of Hiroshima with a junction point at Koi. The entire system, including the route to Miyajima, was electrified. The remaining areas were serviced by motorbuses. Due to the delta formation of Hiroshima made by the Ota River branching into six channels, namely, the Enko, the Kyobashi, the Motoyasu, the Ota, the Temma and the Koi Rivers, a number of bridge crossings was necessary to service each island of the delta. Since there were fewer than 25 private vehicles in Hiroshima, travel by bus, street railway, or railroad was necessary. Within the city proper the greatest recorded traffic occurred during the month of July 1945. It amounted to 4,200,000 passengers, with an additional 800,000 carried by the Miyajima branch line. These figures included bus traffic.

b. The 26 buildings on Figure 2, dispersed over an area of 4.7 acres, constituted the Sendamachi station which served as offices, repair units, warehouses and converter station (Buildings 2 and 24 of Fig. 2 are also Buildings 35A and 35B of the Building Damage Section). Figure 1 also indicates the Yagurashita station which is a single unit supplying power to that part of the city, and is classified as Building 3 in the Building Damage Section. Usage and areas of buildings on Figure 2 are shown in Table 1.

c. The company purchased its electric power from the Chugoku Electric Co., a subsidiary of the Nippon Electric Company, for the two converter stations at Sendamachi and Yagurashita. Both converter stations received electric power at 22 kilovolt AC and converted it to operating voltages of 660 volts DC. Converting equipment at each station was as follows:

(1) Sendamachi converted station: One iron-case rotary converter, German Deutsch type, 500 kilowatt at 600 volts DC, manufactured by the Japan Electric Co., Kyoto, Japan. One motor-generator set, General Electric type MP, 300 kilowatt at 600 volts DC, manufactured by General Electric Co., U. S. A.

(2) Yagurashita converter station: One mercury rectifier, glass type, 480 kilowatt at 600 volts DC, manufactured by the Japan Electric Co., Kyoto, Japan. One rotary converter, 500 kilowatt at 600 volts DC, manufactured by the Shibura Electric Co., Tokyo, Japan.

Both stations were capable of supplying power for 100 street railway cars under normal conditions.

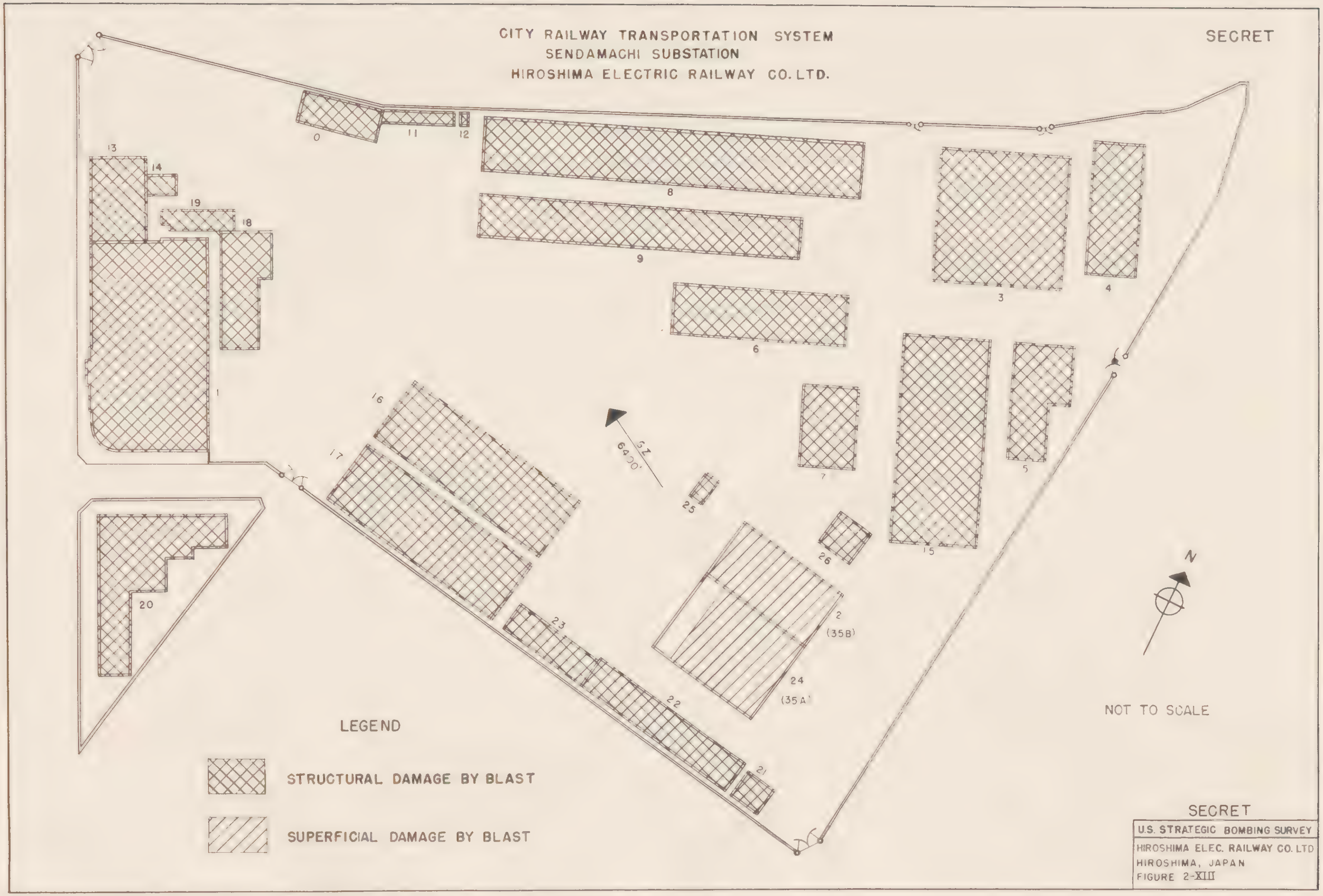
d. The Hiroshima Electric Co. operated 123 cars, 12 of which were normally routed between Koi and Miyajima. The largest car had a capacity (seated and standing) of 160 passengers, weighed 18 tons empty and 26 tons loaded, and was rated at 37.3 kilowatt at 550 volts DC. The average speed of street railway traffic within the city was 15 miles per hour, while that to Miyajima was approximately 25 miles per hour. Since the city of Hiroshima was practically flat, no problem of overloads was encountered. Transmission of power was by an overhead system, and pick-up from overhead to car was made by a transverse bar.

e. The company operated 85 motorbuses to provide transportation for those areas not served by cars. Due to the lack of gasoline, buses were operated by a gaseous fuel which was produced by each vehicle. Chopped wood or coal was placed in an airtight container, and converted to gases by externally applied heat. Speeds up to 35 miles per hour were obtained with busses fully loaded.

f. The repair units at Sendamachi were capable of repairing 50 cars a month, but at no time were required to handle more than 25. Garages were able to repair approximately 25 buses per month.

g. The overhead system consisted of a single, solid copper conductor attached to steel, concrete, or wood poles for each pair of rails. Figure 3 and Figure 1 indicates the types and locations of the poles. The company maintained 1,000 poles within the city, of which 300 were steel, 670 were wood, and 30 were concrete. All poles were set approximately 150 feet apart. A joint ownership of poles was held by the Hiroshima Electric Railway Co., the Chugoku Electric Co., and the Government Communications Agency, each maintaining the poles it had initially installed. By joint agreement, however, all agencies could attach their transmission systems to any pole.

h. The company maintained 15.5 miles of double track within the city and 6 miles of double track between Koi and Miyajima. It also maintained 4 miles of single track which met the double track to complete the system between Koi and Miyajima. The type of rail used for the major part of the track system was the Carnegie rail section, weighing 120 pounds per yard, the re-


CITY RAILWAY TRANSPORTATION SYSTEM
SENDAMACHI SUBSTATION
HIROSHIMA ELECTRIC RAILWAY CO. LTD.
SECRET
0
11
12
13
14
19
18
8
9
3
4
6
1
16
17
7
5
15
25
26
20
23
22
21
2
(35B)
24
(35A)
GZ
6400'
N
NOT TO SCALE
LEGEND
STRUCTURAL DAMAGE BY BLAST
SUPERFICIAL DAMAGE BY BLAST
SECRET
U.S. STRATEGIC BOMBING SURVEY
HIROSHIMA ELEC. RAILWAY CO. LTD
HIROSHIMA, JAPAN
FIGURE 2-XIII

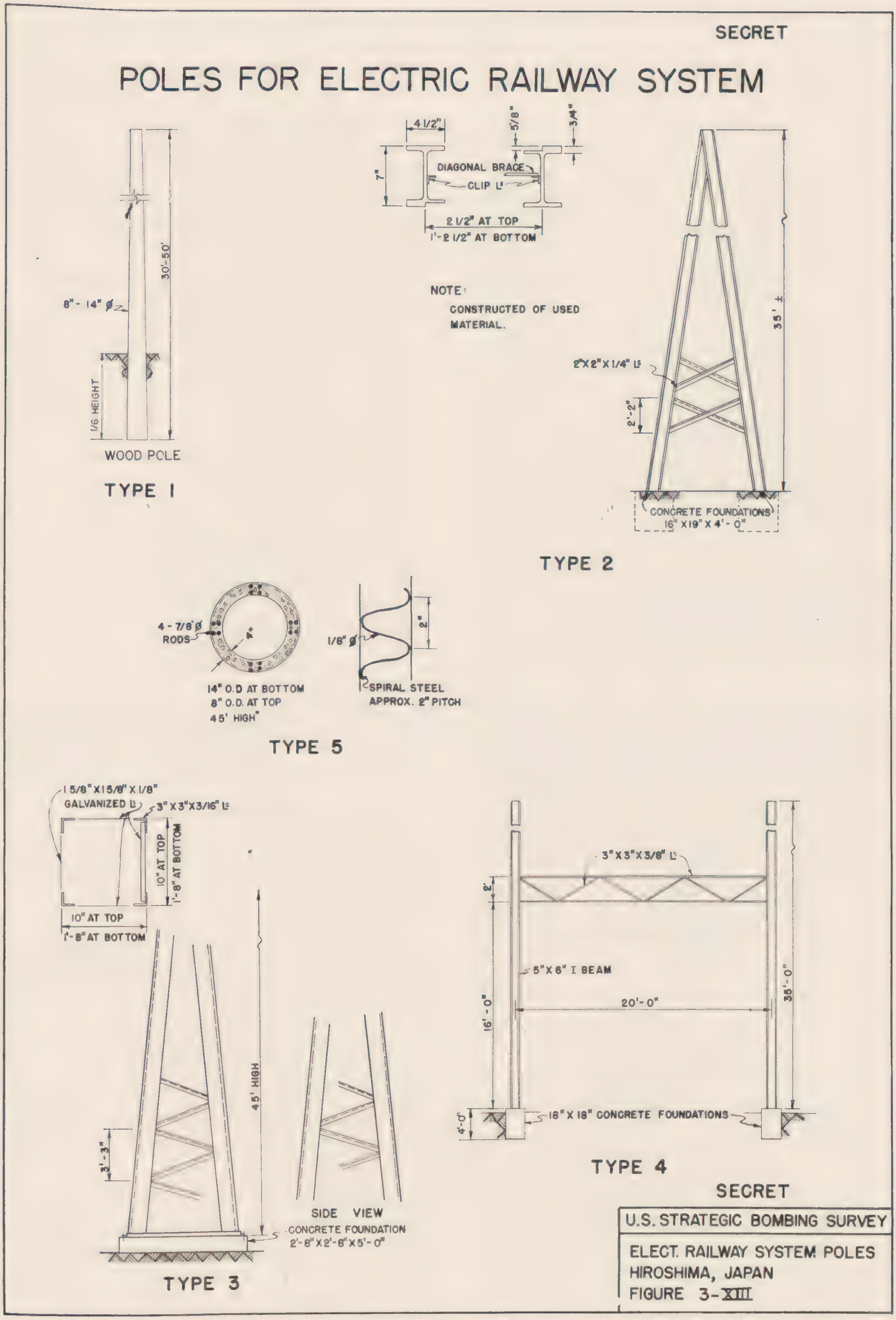

SECRET
POLES FOR ELECTRIC RAILWAY SYSTEM
8" - 14" Ø
30'-50'
1/6 HEIGHT
WOOD POLE
TYPE 1
4 1/2"
5/8"
3/4"
7"
DIAGONAL BRACE
CLIP L^s
2 1/2" AT TOP
1'-2 1/2" AT BOTTOM
NOTE:
CONSTRUCTED OF USED MATERIAL.
2"X2"X1/4" L^s
2'-2"
35' ±
CONCRETE FOUNDATIONS
16" X19" X 4'- 0"
TYPE 2
4 - 7/8" Ø RODS
7"
14" O.D AT BOTTOM
8" O.D. AT TOP
45' HIGH
1/8" Ø
2"
SPIRAL STEEL
APPROX. 2" PITCH
TYPE 5
1 5/8" X 15/8" X 1/8"
GALVANIZED L^s
3" X 3" X3/16" L^s
10" AT TOP
1'-8" AT BOTTOM
10" AT TOP
1'-8" AT BOTTOM
45' HIGH
3'-3"
SIDE VIEW
CONCRETE FOUNDATION
2'-8" X 2'-8" X 5'- 0"
TYPE 3
3" X 3" X 3/8" L^s
2'
5" X 6" I BEAM
16'-0"
20'-0"
35'-0"
4'-0"
18" X 18" CONCRETE FOUNDATIONS
TYPE 4
SECRET
U.S. STRATEGIC BOMBING SURVEY
ELECT. RAILWAY SYSTEM POLES
HIROSHIMA, JAPAN
FIGURE 3-XIII

TABLE 1–XIII.—*Hiroshima city electric railway and bus system buildings—building data*

[Areas in thousands of square feet]

Building	Grid	Usage	Type	Plan area	Stories	Building HE–V	Building fire–V	Distance AZ (feet)	Total floor area	Building damage (floor area)		Equipment damage	
										Structural damage (blast)	Superficial damage (blast)	Percent	Cause
1	7H	Offices	D	7.0	2	V4	C	6,700	14.0	13.6			
2	7H	Substations	A2, 3	3.0	1	V4	C	6,700	6.0	6.0	3.0	5	Blast.
3	7H	Repair shop	D	6.0	1	V4	C	6,700	6.0	6.0			
4	7H	do	D	2.8	1	V4	C	6,700	2.8	2.8			
5	7H	Blacksmith shop	D	2.3	1	V4	C	6,700	2.3	2.3			
6	7H	Paint shop	D	3.9	1	V4	C	6,700	3.9	3.9			
7	7H	Carpenter shop	D	1.7	1	V4	C	6,700	1.7	4.7			
8	7H	No. 1 car barn	D	9.1	1	V4	C	6,700	9.1	9.1			
9	7H	No. 2 car barn	D	5.3	1	V4	C	6,700	5.3	5.3			
10	7H	Dressing room	D	1.1	1	V4	C	6,700	1.1	1.1			
11	7H	Warehouse	D	1.1	1	V4	C	6,700	1.1	1.1			
12	7H	Rest room	D	.1	1	V4	C	6,700	.1	.1			
13	7H	Office	D	1.1	1	V4	C	6,700	1.1	1.1			
14	7H	Rest room	D	.4	1	V4	C	6,700	.4	.4			
15	7H	Bus work shop	D	6.8	1	V4	C	6,700	6.8	6.8			
16	7H	No. 1 garage	D	5.3	1	V4	C	6,700	5.3	5.3			
17	7H	No. 2 garage	D	5.3	1	V4	C	6,700	5.3	5.3			
18	7H	Dining hall	D	3.1	1	V4	C	6,700	3.1	3.1			
19	7H	Nightwatch	D	.5	1	V4	C	6,700	.5	.5			
20	7H	Quarters	D	4.7	1	V4	C	6,700	4.7	4.7			
21	7H	Office	D	.5	2	V4	C	6,700	.5	.5			
22	7H	Warehouse	D	2.5	1	V4	C	6,700	2.5	2.5			
23	7H	do	D	1.1	1	V4	C	6,700	1.1	1.1			
24	7H	do	F2		2	V3A	C	6,700	9.0		3.8		
25	7H	Oil storage	D	.5	1	V4	C	6,700	.5	.5			
26	7H	Bath house	D	.6	1	V4	C	6,700	.6	.6			
Yagura Shita Station	7H	Substation	A2, 3	3.8	1	V4	C	2,200	3.8	3.8		100	Fire and blast.

mainder being a Japanese section approximately 90 pounds per yard, manufactured by the Japan Rail Co., Kyushu. The rails were mounted on 8- by 8-inch ties, 7 feet long. The track gage was 4 feet 8.5 inches, measured between inside faces of rails. As shown on Figure 1, the city proper was built on a delta formation which necessitated a number of bridges to complete the track system. Table 2 lists bridges required for river crossings. (Data are taken from Bridge Damage Section of this report.)

TABLE 2.—*River crossings*

Bridge	Grid	Type	Length (feet)	Ownership
4	5J	Reinforced concrete.	246.5	City of Hiroshima; Electric Railway Co.
13	5I	Steel I-beam	297.0	Hiroshima Electric Railway Co.
17	7H	Plate girder	644.0	City of Hiroshima; Electric Railway Co.
24	4G–H	do	398.0	Preferred Government; Electric Railway Co.
28	3G	Timber	224.0	City of Hiroshima; Electric Railway Co.
35	5G	Steel I-beam	231.0	Hiroshima Electric Railway Co.
44	4F	do	426.0	Do.
47	4E	do	351.0	Do.

In the case of jointly owned bridges an agreement was made to facilitate construction and maintenance, and to reduce the initial cost to each agency.

3. Analysis of Damage

a. The following terms and definitions for building and equipment damage have been used throughout this section:

(1) Building.

(*a*) Structural: Damage to principal load-carrying members (trusses, beams, columns, load-bearing walls, floor slabs in multistory buildings) requiring replacement or external support during repairs. Light members, such as purlins and rafters, are not included.

(*b*) Superficial: Damage to purlins and other light members, stripping of roofing and non-load-bearing exterior walls. Damage to glass and interior partitions not included.

(*c*) Minor: Damage to glass and interior partitions, floor surfaces, and interior trimming.

(2) Machinery, utilities, and equipment.

(*a*) Total: Not worth repair.

(*b*) Heavy: Requiring repair beyond capacity

of normal maintenance staff; usually returned to manufacturer.

(*c*) Slight: Requiring repair within capacity of normal maintenance staff.

b. Of the 26 buildings (Fig. 2) which constituted the Sendamachi station, 6,400 feet from GZ, only Buildings 2 and 24 were usable after the atomic-bomb attack. The remaining structures, which were of wood-frame and timber construction as indicated on Table 1, suffered structural damage from blast (Photos 1 and 2). Since no fires started in the Sendamachi area, all damage was the result of blast. A firebreak immediately north of the area prevented the spread of fires to the south and to the Sendamachi area. The Yagurashita station, which was in another section of the city (Fig. 1) was structurally damaged by blast and fire. Buildings 2 and 24 of the Sendamachi station and the Yagurashita station are listed as Buildings 35A, 35B, and 3, respectively, in Section X, Damage to Buildings. The extent of damage to the remaining structures is given in Table 1.

c. In order to resume business, a single room in Building 1 was salvaged and used as office space but, it being insufficient, cars that had been repaired were utilized temporarily as additional space.

d. Because of the extent of damage to the street-railway and motorbus-repair units and warehouses, repairs to rolling stock were curtailed from 50 to 10 cars and from 25 to 5 motorbuses per month.

e. Equipment damage (Photo 3) in the converter station at Sendamachi was slight. Busbars and electric distribution panels were damaged by either blast or falling debris, but the converter equipment was not short-circuited either by debris or the sudden power cut-off. Damage to the Sendamachi electric substation, which provided electric power for the converter station and the adjoining vicinity, interrupted electrical distribution in the section. By 9 August 1945, the converter station at Sendamachi was repaired and operative, the 22-kilovolt lines being shunted around the Sendamachi electric substation, and a direct connection made to the city railway converter station. This action was possible because of the subsurface circuits to the Sendamachi electric substation. Both converters were available for use, but one was sufficient to operate the cars on the portion of track which was not damaged.

f. The Yagurashita station equipment, 900 feet from GZ (Photo 4), suffered total damage by blast and fire. No equipment was salvageable.

g. Of the 123 cars operated by the company, 99 were in use at the time of the attack and 24 were held in reserve at the Sendamachi station. Of the 85 motorbuses, 70 were being operated while the remaining 15 were under repairs or in reserve. In reporting the damage to rolling stock, the company officials employed other terms and definitions than those used in this report and the combination of both are defined as follows under equipment damage:

(1) Total: Not worth repair. Totally burned.

(2) Heavy: Requiring repair beyond capacity of normal maintenance staff; usually returned to manufacturer.

(*a*) Partly burned.

(*b*) Severe damage: Sufficient damage to prevent use of car. Damaged, collapsed framing; burned-out or damaged motive equipment.

(3) Slight: Requiring repair within capacity of normal maintenance staff.

(*a*) Moderate damage: Sufficient to prevent use of car temporarily-damaged seats and damaged motive equipment that could be readily repaired.

(*b*) Slight damage: Insufficient to prevent use of car—broken windows, displaced seats, but no damaged motive equipment.

The number of damaged and burned cars is shown on Figure 1. A summary of damage for both cars and motor busses (Table 3) follows:

TABLE 3.*—*Damage to cars and buses*
OPERATING AT TIME OF BLAST

Type of vehicle	Damage by burning		Damage by blast		
	Total (totally burned)	Heavy (partly burned)	Heavy (severe)	Moderate	Slight
Cars	22	3	13	16	3
Motor buses	18	3	2	3	5
AT THE SENDAMACHI STATION					
Cars	------	------	10	8	6
Motor buses	------	------	5	4	3

*Japanese classification.

Of the 15 undamaged cars, 12 were operating on the Koi to Miyajima line; the remaining 3, at 10,800 feet from GZ, were protected from the blast by buildings. The 42 undamaged motor buses were

also operating in outlying vicinities. Railway officials stated that cars and buses operating within a radius of 1,500 feet of GZ (photo 5) caught fire immediately on the side facing GZ. Observations were made of damage to cars and buses within the 1,500-foot radius. Evidence of ignition by radiant heat was found in a fire lane along the tracks where burned cars had been blown by blast, substantiating the statements of the railway officials. Cars and buses were blown 30 feet, in some instances, from where they were originally standing. Buses adjacent to buildings were damaged by falling debris. This was especially true of both cars and buses that were standing in the Sendamachi station (Photos 6 and 7). Rolling stock that was burned outside the 1,500-foot radius was ignited by adjacent burning buildings (Photos 8 and 9). Buses were totally damaged 4,000 feet from GZ, and heavily damaged 5,500 feet from GZ. Damaged cars and buses standing in the roadway were removed and placed on side areas in order to facilitate traffic (Photos 10, 11, and 12). The 42 available motor buses permitted some passenger traffic to be maintained. By 9 August 1945 the converter station at Sendamachi was again in operation and 8 cars were available for use, excluding 12 cars routed to Miyajima.

h. The traffic within Hiroshima for the month of October 1945 was 800,000 passengers, and 500,000 were carried on the Miyajima line, which indicated a decrease of 81 percent in traffic rate for Hiroshima, and a 38-percent decrease for the Miyajima line. Because of the reduced speed and small number of cars, the allowable capacity of the large cars was raised from 160 to 200 passengers. Bus capacity was also raised approximately 50 percent.

i. Because the cars and buses were distributed through the city in a nonuniform manner (i. e., many were concentrated in car barns), it was felt that a calculated MAE would have no real significance. Therefore, a graphical method was chosen for presenting both the actual location of each unit at the time of the atomic-bomb explosion, and the extent of damage suffered by it. Figure 1 shows the location of each unit at 0815 hours on 6 August 1945, the time of the attack. Figure 4 presents graphically the number of units suffering damage in each of the three categories, total, heavy, and slight, giving the maximum and minimum distances at which such damage occurred. No minimum distance is given for total damage, as an examination of the diagram indicates the likelihood that any unit within 2,300 feet of GZ (the minimum distance for units suffering less than total damage) would have suffered total damage. Street railway cars were totally damaged up to 6,700 feet and heavily damaged up to 8,400 feet from GZ; buses suffered total and heavy damage up to 4,000 feet and 5,500 feet from GZ, respectively.

j. Of the 15.5 miles of railway system, 11.4 miles of overhead transmission were heavily or totally damaged (Fig. 1) directly as a result of the blast or by fires subsequent to the blast. Results of a survey by the company, accounting for 500 wood poles and 100 steel poles damaged by fire and blast (Photos 15 through 21) owned by them are shown in Table 4, giving the maximum limit of damage.

TABLE 4.—*Damage to poles*

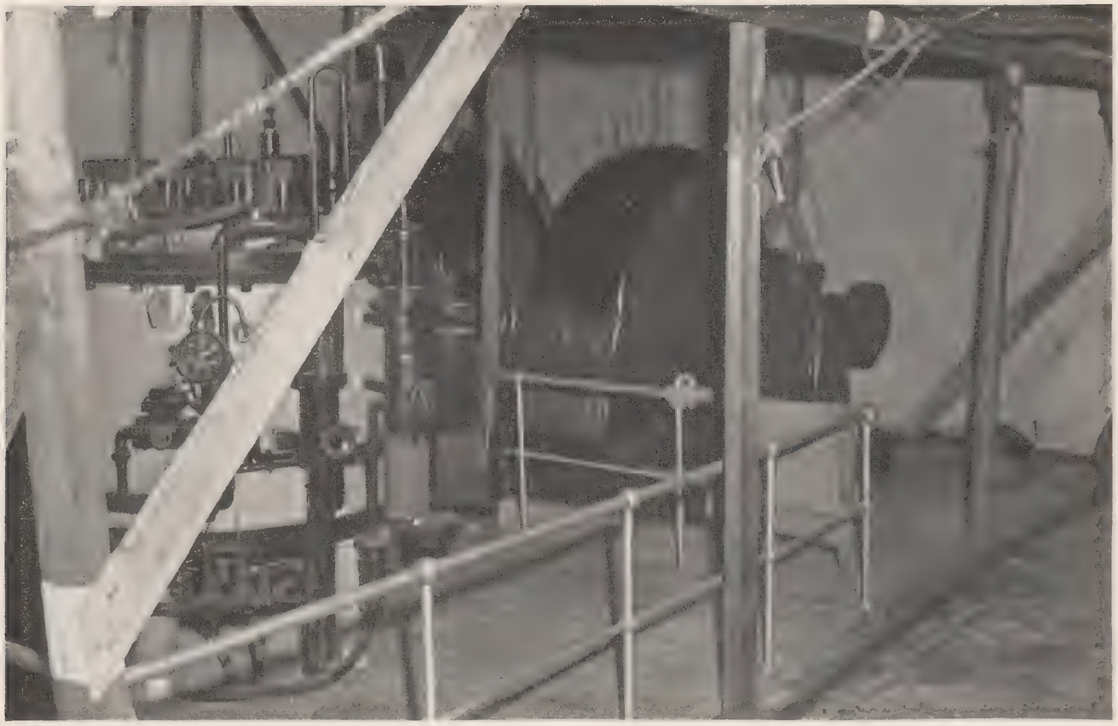
Type of pole	Material	Damage (distance in feet from GZ)		
		Blast	Burned	Tilted
Type 1	Wood	4, 500	6, 500	7, 500
Type 2	Steel rail	3, 500	-------	3, 500
Type 4	Built-up pole	3, 000	-------	3, 500
Type 5	Concrete			

Type 3 poles were owned and maintained by the Chugoku Electric Co., but the Hiroshima Railway Co. was allowed the privilege of overhead attachment because of the joint agreement previously mentioned. The steel-lattice poles were bent at the base by the force of the blast at 6,000 feet from GZ (Photo 22). The concrete poles at 6,000 feet (Photo 23) from GZ were undamaged. Although poles were intact and standing, the overhead cable was blown down by blast 8,000 feet from GZ (Photo 24). Some new poles necessary to operate the portions of the system in use were installed, and the partly damaged poles were utilized. The whole system was of a temporary nature and replacement of the majority of the overhead lines would have been essential for continued operations.

k. No actual damage to the track system, except at bridges, could be determined either by the railway company or by the members of the team. Bridge 13 (Photos 25 and 26) was depressed approximately 20 inches, preventing traffic over the Kyobashi River. Bridge 24 was subjected to a

PHOTO 1–XIII. Blast damage to offices and adjacent buildings at the Sendamachi substation, 6,400 feet from GZ.

PHOTO 2–XIII. Blast damage to warehouse at the Sendamachi substation.



PHOTO–3–XIII. Converter equipment at Sendamachi Substation, 6,400 feet from GZ.

PHOTO–4–XIII. Damaged converter equipment at Yagurashita substation, 900 feet from GZ.

PHOTO 5–XIII. Damage to car at an intersection 1,000 feet east of GZ. Damaged car to left; others are in operation.

PHOTO 6–XIII. Damage to buses at the Sendamachi substation 6,400 feet from GZ.

PHOTO 7–XIII. Damage to cars in car repair unit at Sendamachi substation, 6,400 feet from GZ.

PHOTO 8–XIII. Damage to car 2,000 feet southeast of GZ.

PHOTO 9–XIII. Damaged car 4,000 feet northwest of GZ.

PHOTO 10–XIII. Damaged car 2,000 feet east of GZ.

PHOTO 11–XIII. Damaged bus 2,500 feet east of GZ.

PHOTO 12–XIII. Damage to car 3,000 feet northeast of GZ.

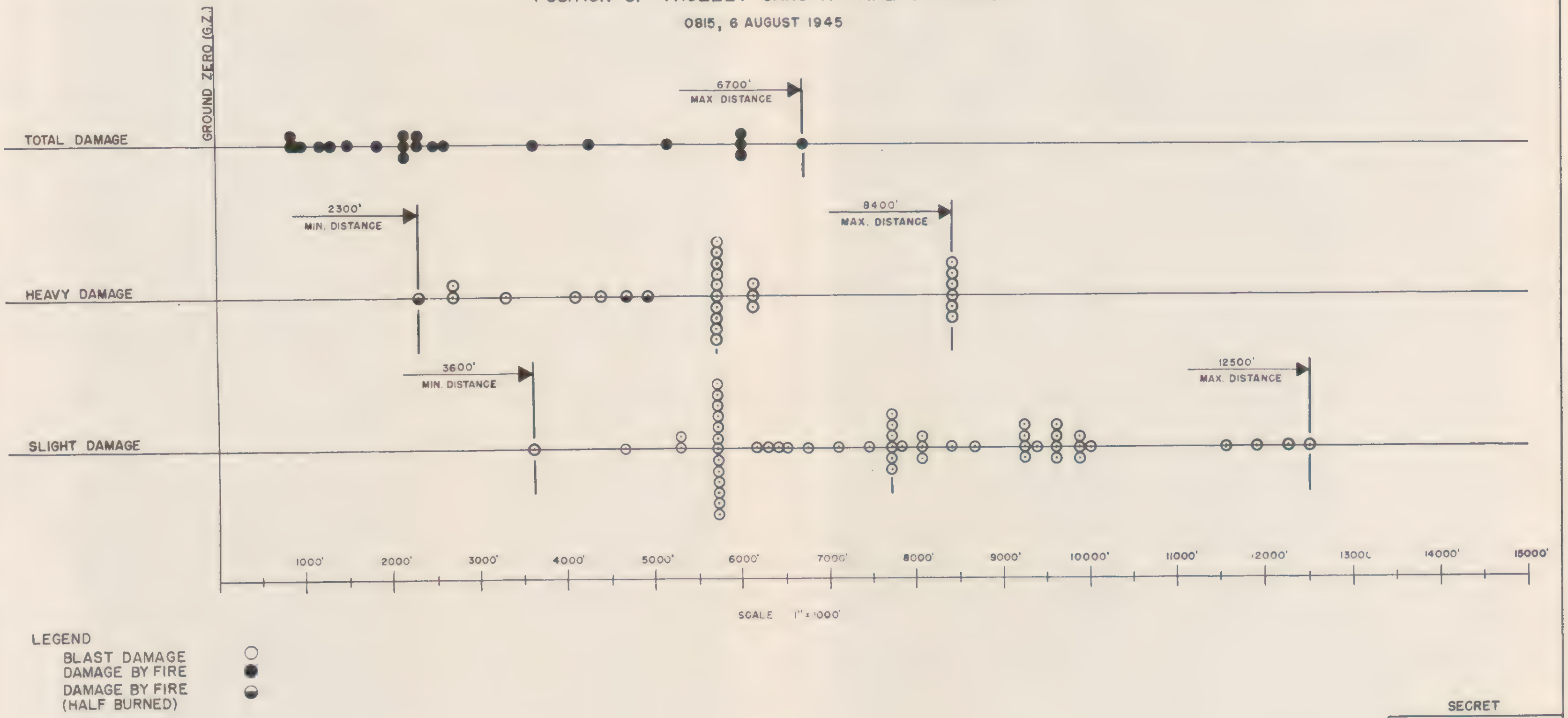
PHOTO 13–XIII. Blast damage to pole and car 4,000 feet southwest from GZ.

PHOTO 14-XIII. Blast damage to cars 9,000 feet southwest of GZ. Because of the extent of damage to the overhead transmission system in the Eba area (Fig. 1) no effort was made to put this section of streetcar line in service and consequently return the cars in the above photograph to Sendamachi for repairs.

SECRET

POSITION OF TROLLEY CARS AT TIME OF ATTACK

0815, 6 AUGUST 1945



SECRET

U.S. STRATEGIC BOMBING SURVEY

DAMAGE TO TROLLEY CARS
HIROSHIMA, JAPAN
FIGURE 4 XIII

PHOTO 15–XIII. Blast damage to steel poles, 600 feet from GZ, and wood pole replacements.

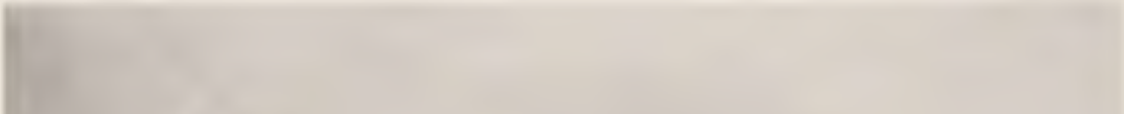


PHOTO 16–XIII. Wood poles broken off at ground by blast 600 feet from GZ.

PHOTO 17–XIII. Blast damage to poles 2,000 feet west of GZ.

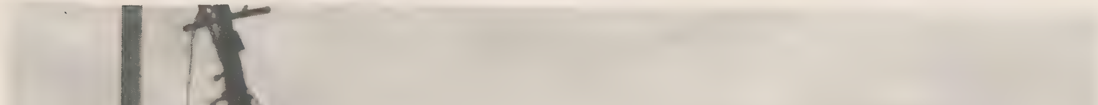


PHOTO 18–XIII. Bent steel and fractured wood poles 3,000 feet southeast of GZ.

PHOTO 19–XIII. Blast damage to wood and steel poles 2,500 feet northwest of GZ.

PHOTO 20–XIII. Damaged cross arms 3,000 feet west of GZ.

PHOTO 21–XIII. Blast damage to steel pole 3,500 feet from GZ.

PHOTO 22–XIII. Damage to steel poles 6,000 feet southeast of GZ.

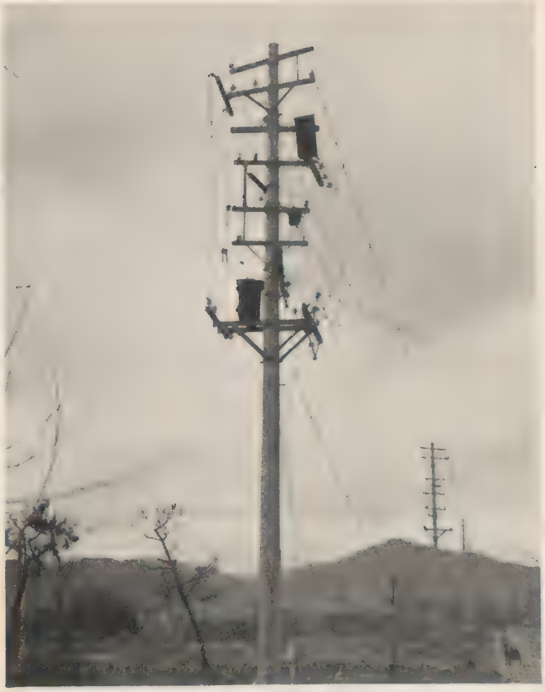


PHOTO 23–XIII. Standing concrete poles 6,000 feet east of GZ.

PHOTO 24–XIII. Damaged overhead 8,000 feet southeast of GZ.

PHOTO 25–XIII. Streetcar Bridge (13) damaged by blast and flood, 4,700 feet from GZ.

PHOTO 26–XIII. Temporary repairs to stabilize car tracks on Bridge 13.

PHOTO 27–XIII. East approach to Bridge 24 showing blast damage. 1,000 feet from GZ.

PHOTO 28–XIII. West approach to Bridge 24 showing displaced tracks.

PHOTO 29–XIII. Bridge 17 showing high water on 23 October 1945.

PHOTO 30–XIII. Flood damage at Bridge 35. Ferry transportation across the Temma-Gawa.

PHOTO 31–XIII. Undamaged, street car over-crossing at Bridge 4, 6,500 feet from GZ.

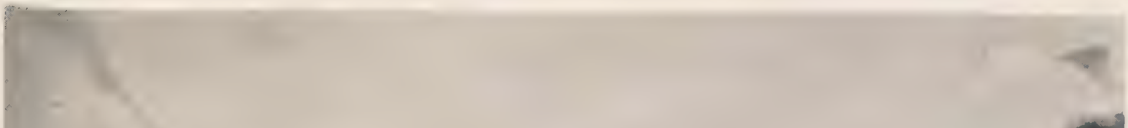


PHOTO 32–XIII. Undamaged, street car over-crossing at Bridge 44, 5,300 feet from GZ.

severe depressive and rebound action that displaced tracks (Photos 27 and 28) on the bridge. In addition to damage attributed to the attack, the severe floods of 17 September 1945 and 5 October 1945 damaged Bridges 28 and 35 (Photo 30). Bridge 13 was also further damaged by floods. The following (Table 5) is taken from Section XII, Damage to Bridges, bound herewith, and indicates the damage to bridges in each instance:

TABLE 5.—*Damage to bridges*

Bridge No.	Grid No.	Dist. from GZ (feet)	Type	Damage classification	Cause
4	5J	6, 400	Concrete	None	
13	5I	4, 600	I-beam	Moderate	Blast and flood.
17	7H	7, 600	Plate girder	None	
24	4H	1, 000	do	Slight	Blast.
28	3G	4, 500	Timber	Complete destruction	Flood.
35	5G	3, 200	I-beam	do	Do.
44	4F	5, 300	do	None	
47	4E	7, 400	do	do	

Damage classification is as follows:

Complete destruction.—Complete destruction of structure requiring replacement of entire bridge or within 10 percent of all spans or bents or both; damage requiring from 90 to 100 percent replacement of spans and piers.

Severe damage.—Complete destruction of the major part of the structure or such damage that would require replacement of more than half of the spans or bents; damage requiring replacement of between 50 and 90 percent of the spans and piers.

Moderate damage.—Damage or destruction of whole or part of spans or bents of structure that could be replaced or repaired in a relatively short time, the amount of damage not to exceed half of the entire structure, i. e., damage requiring replacement of between 10 and 50 percent of the spans and piers.

Slight damage.—Damage to portions of spans or piers of structure that would necessitate a minimum of repair or replacement.

l. Because of damaged poles and overhead system, the only portion of track usable after the attack was that between the Sendamachi substation and Ujina, but by 12 September 1945 the section between Koi and the Sendamachi substation via Dobashi, Tokaichimachi, and Takanobashi was placed in service. The Japanese army assisted in these repairs in order to facilitate the transportation of personnel. By 12 October 1945 the track system between Kamiyacho and the terminal at the government railway station, via Hachobari, Matobacho, and Hiroshimaekimae, was operative but repairs to Bridge 13 had not been completed until 1 November 1945. The only portions of the track system not in operation were those between Tokaichimachi and Yokogawa, Dobashi and Eba, Hachobari and Hakushima, and Matobacho and Senbaikyokumae. Figure 1 indicates the progress of replacement. The loss of Bridge 35 during the flood period hampered transportation only insofar that passengers had to cross the river by ferry (Photo 30) or by other bridges on foot, and take the shuttle between Koi and the Temma River.

4. Recommendations and Conclusions

a. The Sendamachi station, which was 6,400 feet from GZ, received severe structural damage by blast, but no fire damage. Buildings 2 and 24 (Table 1) suffered only superficial damage, while the remaining buildings, which were poorly constructed, were structurally damaged. The converter station at Sendamachi was only slightly damaged, being housed in Building 2, and was operative in a few days. The Yagurashita station, at 900 feet from GZ, constructed of brick, was structurally damaged by blast and fire. Thus, dispersal of converter stations offered effective protection against the attack.

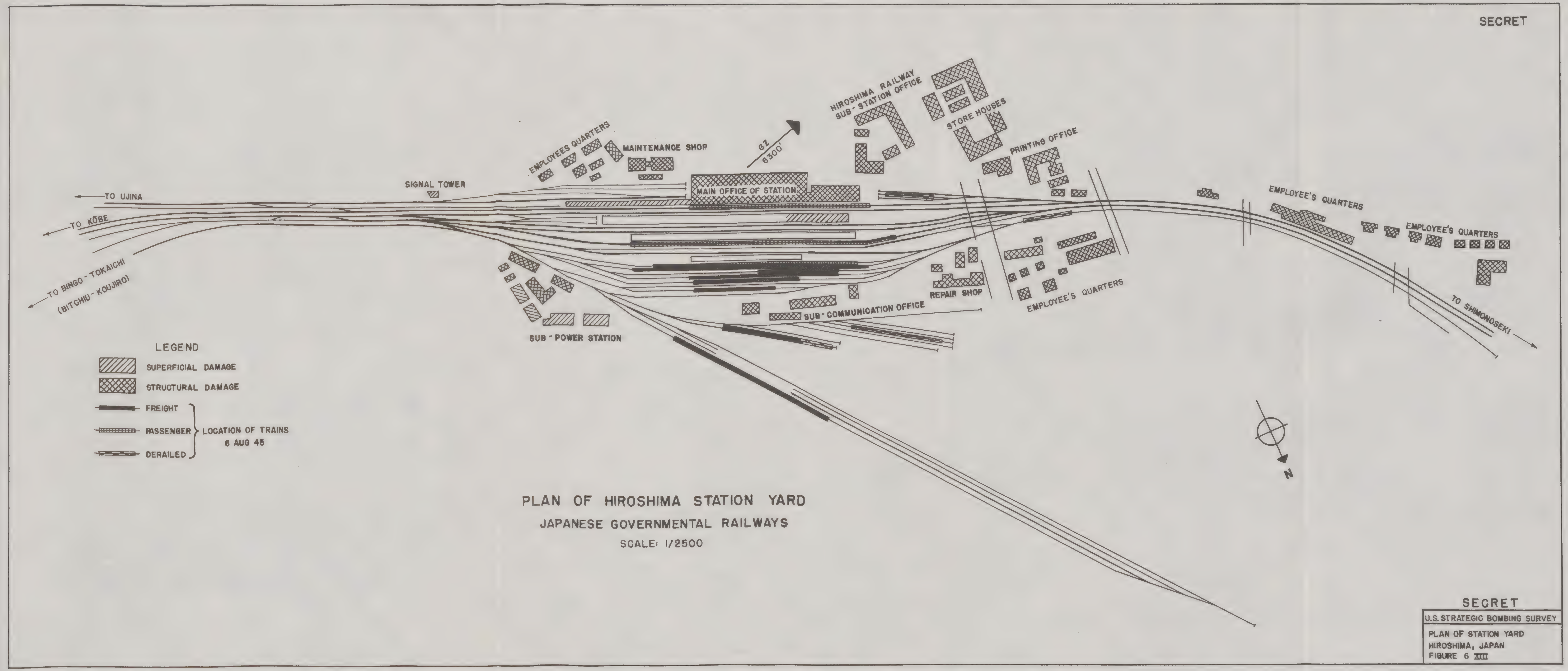
b. The overhead transmission system maintained by the city electric railway system was particularly vulnerable to an air-burst bomb of this type. The wood pole, or Type 1, although more easily installed and replaced, proved more vulnerable to blast and fire than the steel-rail pole or Type 2. Comparison of the amount of replacement of both types of poles indicates that the type 2 pole, being more resistant to fire and blast, therefore requiring fewer replacements, is the more practical. Replacement of the overhead conductors could be facilitated on this type of pole, and a greater part of the system would be operative in a shorter time. A subsurface system such as that used in some cities in the United States to eliminate an overhead transmission system appears to be the best solution.

B. GOVERNMENT RAILROAD SYSTEM

1. Summary

a. Location. The Government railways of Japan was the only railway system providing intercity transportation for Hiroshima. It maintained the double-track roadbed called the Sanyo Main Line, as well as classification yards, repair facilities, transit sheds, and complete station facilities at Hiroshima. A single-track roadbed connected with Ujina, the only deep-water harbor in this area, to provide rail to ship transportation for military material and personnel to continental Asia and other theaters of operations. Transit sheds and stations were also maintained at Koi and Yokogawa, intermediate points within Hiro-


HIROSHIMA
GOVERNMENT RAILROAD SYSTEM
LEGEND
DOUBLE TRACK
SINGLE TRACK
TRACK GAGE 3'-4"
SECRET
SHINJOBASHI STATION
TO BITCHIU-KAJIRO
KABE LINE (ELECTRIC)
OTA GAWA
YOKOGAWA STATION
GEIBI LINE
OLD CASTLE
HIROSHIMA STATION YARD
KOI STATION
ZERO POINT
PROBABLE LIMIT OF DAMAGE TO FREIGHT CARS (6800 FT RADIUS)
FUKUSHIMA GAWA
HIROSHIMA CLASSIFICATION YARD
SAN-YO MAIN LINE
ENKO GAWA
KOI GAWA
KYOBASHI GAWA
TO SHIMONOSEKI
TEMMA GAWA
OTA GAWA
MOTOYASU GAWA
UJINA LINE
MUKAINADA STATION
SAN-YO MAIN LINE
TO KOBE
UJINA STATION
HIROSHIMA
HIROSHIMA PREFECTURE, HONSHU, JAPAN
CONTOUR INTERVAL 20 METERS
KAITA WAN (BAY)
TYPICAL FILL SECTION
33'-6"
9'
3'4"
8'-8"
8"x8"x9'-0"
REMOVABLE TOP
3'-0"
2'-3"
1'-0"
1'-6"
BALLAST
EARTH FILL
1 1/2:1
COMMUNICATIONS CABLE TRENCH
HIROSHIMA-KO (HARBOR)
HIROSHIMA WAN (BAY)
SECRET
U.S. STRATEGIC BOMBING SURVEY
GOVERNMENT RAILROAD SYSTEM
HIROSHIMA, JAPAN
FIGURE 5-XIII


SECRET
TO UJINA
TO KŌBE
TO BINGO - TOKAICHI (BITCHIU - KOUJIRO)
SIGNAL TOWER
EMPLOYEES QUARTERS
MAINTENANCE SHOP
GZ 6300'
HIROSHIMA RAILWAY SUB - STATION OFFICE
STORE HOUSES
PRINTING OFFICE
MAIN OFFICE OF STATION
EMPLOYEE'S QUARTERS
EMPLOYEE'S QUARTERS
EMPLOYEE'S QUARTERS
TO SHIMONOSEKI
REPAIR SHOP
SUB - COMMUNICATION OFFICE
SUB - POWER STATION
LEGEND
SUPERFICIAL DAMAGE
STRUCTURAL DAMAGE
FREIGHT
PASSENGER
DERAILED
LOCATION OF TRAINS 6 AUG 45
N
PLAN OF HIROSHIMA STATION YARD
JAPANESE GOVERNMENTAL RAILWAYS
SCALE: 1/2500
SECRET
U.S. STRATEGIC BOMBING SURVEY
PLAN OF STATION YARD
HIROSHIMA, JAPAN
FIGURE 6 XIII


PLAN OF HIROSHIMA CLASSIFICATION YARD
JAPANESE GOVERNMENTAL RAILWAYS
SCALE: 1/2500
SECRET
LEGEND
NO DAMAGE
SUPERFICIAL DAMAGE
LOCATION OF TRAINS 6 AUG 45
TO KŌBE
SAN-YŌ LINE
OPERATING MAIN OFFICE
SIGNAL TOWER
STORAGE TRACKS
REPAIR SHOP FOR ELECTRIC EQUIPMENT
STORE HOUSE
EXAMINATION HALL
WAREHOUSE
WAREHOUSE
UJINA LINE
TO UJINA
UJINA LINE
RESIDENCE
RESIDENCE
BOILER HOUSE
FORGE
GZ 8700'
NO. 1 ROUND HOUSE
MAIN OFFICE
N
WAREHOUSES
CAR INSPECTION OFFICE
TRANSIT SHEDS
FREIGHT TRANSIT SHEDS
TRANSIT SHED
UJINA LINE
TO HIROSHIMA STA.
SANYŌ LINE
SIGNAL TOWER
TO SHIMO-NOSEKI
EAST PASSENGER TRAIN MAKE-UP TRACKS
LOCOMOTIVE HOUSE
OIL TANK
MAIN OFFICE
WAREHOUSE
LOCOMOTIVE INSPECTION OFFICE
BOILER HOUSE
NO. 2 ROUND HOUSE
TRACK WAREHOUSE
WARE HOUSES
WAREHOUSE
TO BITCHIU-KĀJIRO
GEIBI LINE
SECRET
US STRATEGIC BOMBING SURVEY
PLAN OF CLASSIFICATION YARD
HIROSHIMA, JAPAN
FIGURE 7 XIII

shima. Figure 5 shows all lines and stations. A total of 8,467 persons was employed by the Government railways in the Hiroshima area prior to the attack of 6 August 1945.

b. Traffic. The average passenger rate per month was 1,824,960 persons; the average monthly tonnage in freight handled was 9,300 tons, requiring 620 cars. A total of 6,000 cars per month, however, was shunted through the yards.

c. Repair Facilities. The repair facilities were capable of repairing all engines, tenders, and cars, with the exception of the electric cars which were sent to Hatabe, near Kyoto.

d. Roadbed. The roadbed in the area was a fill section with a gravel ballast, as shown in Figure 5.

e. Bridges. The Sanyo Line crossed the branches of the Ota River to the north, thereby limiting the number of over-crossings to four major, and a number of minor bridges for vehicular traffic.

f. Building Damage. The majority of buildings within the classification and repair area (Fig. 7) which were between the radii of 8,000 and 10,000 feet from GZ were damaged by blast, while those in the station area (Fig. 6) between the radii of 5,800 and 7,400 feet were damaged by fire. Table 8 indicates the extent of damage to buildings within the Koi and Yokogawa area. All buildings in this report are classified by the Building Damage Section, and any conclusions drawn therein for the mean areas of effectiveness will also apply to buildings included in this section. There was no repair-equipment damage in the classification or repair areas.

g. Locomotive Damage. There was no damage to locomotives other than glass breakage.

h. Car Damage. Of the 700 freight cars in the Hiroshima division, 45 were damaged by fire and 46 by blast, amounting to 13 percent of the total; of the 91 passenger cars, 6 were damaged by fire and 77 by blast, or 93 percent of the total; and of the 16 electric cars, 6 were damaged by fire and 6 by blast, or 75 percent of the total. The maximum limit of distance in which probable damage to freight cars might occur was approximately 6,800 feet from GZ, but since 93 percent of the passenger cars were damaged within the 6,800-foot radius and 75 percent of the electric cars were damaged at 6,300 feet, the maximum limit for passenger and electric cars was beyond 6,800 feet from GZ. No passenger cars were found beyond the limits stated.

i. Trackage and Bridge Damage. There was no damage to trackage or bridge crossings. Communications and signalling facilities were not operative because of damage to the communications office in the station area.

j. Cost. The total cost of damage to the Government railroads as estimated on 15 November 1945 was 15,800,000 yen, or $3,950,000 at the 4-yen-to-$1 rate of exchange.

k. Casualties. Of the 8,467 persons employed, 198 were killed, 140 were missing, 934 were seriously injured, and 1,195 sustained minor injuries.

2. The System

a. The locations of buildings and trackage of the government railways systems for the Hiroshima District are indicated on Figures 5, 6, and 7, showing repair units, transit sheds, and passenger depot.

b. The government railways, operating the bulk of the railroad systems in Japan, provided all freight and passenger transportation to and from Hiroshima. As noted on Figure 5, the double-track system known as the Sanyo Main Line skirts the city in a semicircle. The classification yards, repair yards, and passenger stations were part of the system. In locating the tracks at the northern part of the city the river crossings of the deltas of the Ota River were reduced to a minimum number, being over the Kyobashi, the Ota, and the Yamate Rivers. Ujina, the only island with a harbor sufficiently deep to accommodate ocean-going vessels, was connected to the Hiroshima freight yards by a single-track line to facilitate the embarking of military personnel and matériel for continental Asia. The average number of passengers transported per month in the Hiroshima district was 1,824,960, exclusive of military personnel. Through the war years the average tonnage in freight carried was 9,300 tons per month, requiring 620 freight cars, but a total of 6,000 cars a month was routed through the freight yards.

c. Figures 6 and 7 indicate all the buildings within the limits of the Hiroshima railroad freight and passenger areas, including the roundhouses and passenger stations. This was the main section of the Hiroshima subdivision where major repairs to engines, freight and passenger cars were made. Minor repairs to electric cars were also made at Hiroshima, but major repairs were performed at the shops in Hatabe, northwest of Kyoto. Since all locomotives in this area were the coal-burning type, coal bunkers were necessary.

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The Hiroshima division maintained 3 fueling bunkers consisting of a 100-, a 120-, and a 150-ton bunker, respectively. The output of the 3 bunkers was 500 tons of coal per day. A 10-ton traveling crane was used for coaling operations.

d. The printing office, passenger station, and roundhouse were surveyed by the Building Damage Section as Buildings 120, 121, and 126, respectively. All the other buildings were classified as wood-frame, commercial-industrial structures or light-frame, domestic structures.

e. The largest locomotives in the Hiroshima area were those classed as D51 and D52 series which weighed 77 and 85 tons, respectively. The tender for each type was the same and weighed 44.7 tons loaded. The drawbar pull could not be obtained, but the maximum train consisted of 65 freight cars of various tonnages. The average train consisted of between 40 and 50 freight cars. The freight handled in the Hiroshima freight yards, as mentioned in Paragraph 2*b*, required the use of 48 locomotives per day. This figure included through trains which were routed via Hiroshima. The following (Table 6) is a tabulation of passenger and freight car sizes in tons as given by the government railways office:

TABLE 6.—*Freight and passenger car sizes*

Type of car	Net weight (tons)	Capacity (tons)
Passenger cars:		
Large	35. 64	49. 64
Medium	34. 00	38. 00
Small	18. 81	22. 81
Freight cars:		
Large	27. 00	50. 00
Medium	6. 00	18. 00
Small	4. 00	8. 00

f. All rolling stock was manufactured under the supervision of the government railways agency. The rate of repairs of all rolling stock at the Hiroshima district was as follows:

TABLE 7.—*Repair data for rolling stock*

Type	Rate of reapirs per month
Locomotives, Types D51 and D52	13
Tenders for D51 and D52	13
Passenger cars	40
Freight cars	130

TABLE 8–XIII.—*Hiroshima government railroad system buildings—building data*

KOI STATION

[Areas in 1,000's of square feet]

Building	Grid	Usage	Type	Plan area	Stories	Building HE–V	Building Fire–V	Distance AZ (feet)	Total floor area	Building damage (floor area): Structural damage: Blast	Structural damage: Fire	Structural damage: Mixed	Damage: Blast	Damage: Fire	Minor damage	Equipment damage: Per cent	Equipment damage: Cause
	4E	5 residences	D	3.2	1	V–4	C	7,800	3.2				2.4				
	4E	Quarters	D	2.5	1	V–4	C	7,800	2.5				1.8				
	4E	Station	A2.3	21.8	1	V–4	C	7,800	21.8				16.2				
	4E	Transit shed	A2.3	17.5	1	V–4	C	7,800	17.5				5.7				
	4E	Warehouse	D	5.7	1	V–4	C	7,800	5.7				1.3				

YOKOGAWA STATION

Building	Grid	Usage	Type	Plan area	Stories	Building HE–V	Building Fire–V	Distance AZ (feet)	Total floor area	Building damage (floor area): Structural damage: Blast	Structural damage: Fire	Structural damage: Mixed	Damage: Blast	Damage: Fire	Minor damage	Equipment damage: Per cent	Equipment damage: Cause
	3H	7 residences	D	4.5		V–4	C	6,300	4.5		4.5						
	3H	Quarters	D	5.8		V–4	C	6,300	5.8		5.8						
	3H	Station	A2.3	21.3		V–4	C	6,300	21.3		21.3						
	3H	Transit shed	D	8.5		V–4	C	6,300	8.5		8.5						
	3H	Warehouse	D	2.2		V–4	C	6,300	2.2		2.2						
	3H	Garage	A2.2	5.7	1	V–4	N	6,300	5.7				5.7				

These figures include the repairs of electric passenger cars which received only minor repairs at Hiroshima. Government officials estimated that approximately 60 locomotives, 91 passenger cars, 700 freight cars, and 16 electric railway cars were in the Hiroshima vicinity at the time of the attack.

g. The stations at Yokogawa and Koi (Fig. 5) which were also within Hiroshima constituted part of the Hiroshima railroad division. Yokogawa was the terminal point of the Kabe Electric Rail-

way. Table 8 lists all buildings at the Koi and Yokogawa stations. The garage building at the Yokogawa station is identified as Building 75 in the Building Damage Section.

h. The track system indicated in Figure 5 shows all track within the Hiroshima vicinity, including the classification yards. The Sanyo line, or main line, was a double-track roadbed through the city, crossing the Ota River delta on the north side of the city, while the roadbed to Ujina was single track. The crossings of the branches of the Ota River were as follows:

TABLE 9.—*Bridge crossings*

River	Grid	Bridge No.	Bridge type	Spans	Length (feet)	Remarks
Enko	3I	9	Plate girder	7	489	Double track.
Ota	3H	26	do	11	825	Do.
Yamate	3G	50	do	10	390	Do.
Dry stream	3G	51	do	2	66	Do.
Enko	5J	2	do	10	450	Single track.

The above data are taken from the Bridge Damage Section.

i. There was also a number of crossings over highways constructed of steel beams, approximately 20 feet in length. The track bed between the Enko and the Yamate Rivers was built on a fill section averaging approximately 12 feet in height. Figure 5 shows the detail of the roadbed fill section, complete with ties, rails, and communications system. The equivalent of a 100-pound-per-yard rail, manufactured by the Japan Rail Co. was used.

j. There were 8,467 persons employed by the government railways at Hiroshima prior to 6 August 1945.

3. Analysis of Damage

a. The government railways printing office and the passenger station indicated on Figure 6 were listed as Buildings 120 and 121, respectively, by the Building Damage Section. All the remaining buildings on Figure 6, being residences, offices, and lodgings, were classified as light-frame, domestic structures. This building area was between 5,800 and 7,400 feet from GZ, and the majority of the structures was damaged by fire (Photos 33 through 35). Due to the drop in pressure in water lines and lack of electricity for auxiliary pumps, little could be done toward stemming the fires in the station area. Roundhouse 1, which is listed as Building 126 by the Building Damage Section, and the warehouses, repair shops, and engine sheds (Fig. 7) which were classified as wood-frame, commercial-industrial structures were damaged by blast (Photos 36 through 44). Roundhouse 1 received only minor damage (Photo 45). This area was between 8,000 and 10,000 feet from GZ. Because of the disruption of power facilities at the Dambara substation from which the railroad electrical equipment was supplied, no electrical power was available. Bunkers, cranes, and pedestrian overcrossings were undamaged (Photos 46 and 47), but lack of electrical power prevented the coaling operations of the cranes. When electrical power was restored on 9 August 1945, coaling service was resumed, and repairs in the roundhouse were continued.

b. Figures 6 and 7 show the locations of passenger and freight cars on the morning of 6 August 1945. At that time there were 91 passenger cars and 125 freight cars in the passenger station area, as shown on Figure 6, and 486 freight cars in the classification area, as shown on Figure 7. All damage to both passenger and freight cars in the passenger station area was caused by blast and by fire from adjacent burning buildings. The overturned freight cars indicated on Figure 6 were the result of blast, but government railroad officials stated that no passenger cars were overturned. This was probably due to the protection that the passenger station (Building 121) offered, whereas the freight cars were in more open areas. This area is between 5,800 and 6,800 feet from GZ. No freight-car damage was sustained in the classification or repair area, according to yard officials, nor was there damage to locomotives. In reporting the damage to rolling stock the Government railways officials employed terms and definitions other than those used in this report. The combinations of both are defined as follows:

(1) Total: Not worth repairs. Completely burned.

(2) Heavy: Requiring repair beyond capacity of normal maintenance staff, usually returned to manufacturer or repair section.

(*a*) Partly burned.

(*b*) Severely damaged, cannot be used without repairs by the repair section.

(3) Slight: Requiring repair within capacity of normal maintenance staff.

(*a*) Moderate damage, can be used temporarily but must be repaired by repair section for continued service.

PHOTO 33–XIII. Passenger station and shelter damaged by fire and blast, 6,300 feet from GZ.

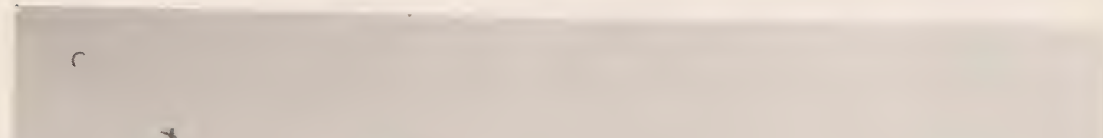


PHOTO 34–XIII. Railroad printing building damaged by fire, 5,800 feet from GZ.

PHOTO 35–XIII. General view of passenger station area showing bomb damage, 6,300 feet from GZ.

PHOTO 36–XIII. Roof stripped from transit sheds by blast. 8.500 feet from GZ.

PHOTO 37–XIII. Transit sheds damaged by blast, 8,700 feet from GZ.

PHOTO 38–XIII. Superficial blast damage to transit sheds, 8,500 feet from GZ.

PHOTO 39-XIII. Engine inspection building damaged by blast, 9,800 feet from GZ.

PHOTO 40–XIII. Warehouses damaged by blast, 9,500 feet from GZ.

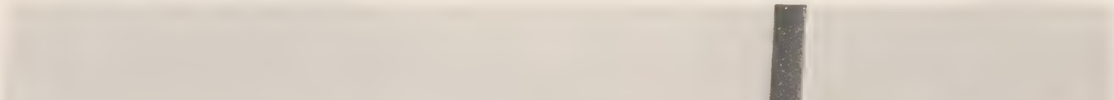


PHOTO 41–XIII. Office and warehouse damaged by blast, 9,100 feet from GZ.

PHOTO 42–XIII. Classification and repair area, 8,500 feet from GZ, showing general damage.

PHOTO 43–XIII. Classification area. Buildings damaged by blast, 9,600 feet from GZ.

PHOTO 44–XIII. Warehouses damaged by blast, 9,200 feet from GZ.

PHOTO 45–XIII. Roundhouse, showing minor blast damage, 8,700 feet from GZ.

PHOTO 46–XIII. Undamaged coal bunkers and crane on south side of Roundhouse 1, 8,900 feet from GZ.

PHOTO 47–XIII. Undamaged pedestrian over-crossing south of passenger station, 6,900 feet from GZ.

PHOTO 48–XIII. Yokogawa station area showing fire damage 6,000 feet from GZ.

(*b*) Slight damage can be used; repairs made by train crew.

All car damage is summaried as follows:

TABLE 10.*—*Passenger and freight or damage*

Type of car	Damage by burning		Damage by blast		
	Total (totally burned)	Heavy (partly burned)	Heavy (severe)	Moderate	Slight
Passenger cars:					
Steel	4		8	12	20
Wood	2		15	2	20
Freight cars:					
Steel	5		8		
Wood	4		17		2

*Japanese classification.

c. All buildings in the Koi station area, 7,800 feet from GZ, received superficial damage. With the exception of the garage (Building 75 of the Building Damage Section), all buildings within the Yokogawa area (Photo 48), 6,000 feet from GZ, were destroyed by fire. Information was not available from the government railroad officials regarding the collapse of structures by blast prior to the burning. Damage to buildings in the Koi and Yokogawa station area is shown on Table 8.

d. At the time of the attack, train 377 was proceeding toward Bridge 9 over the Enko River. The train was made up of 49 miscellaneous freight cars and a locomotive of the D51 type. When the locomotive had crossed 300 feet of the 490-foot bridge the blast wave reached the train. Of the 49 cars, 10 on and 24 off the bridge were completely overturned, or were off the tracks and tilted; also, of 7 cars derailed but upright, 1 was on the bridge and 6 off. The locomotive received only broken glass damage, but the rear trucks of the tender were derailed. None of the train crew was killed, but minor injuries were suffered by a few. The locomotive was disconnected immediately and run to the west abutment of Bridge 9. It was reported by the train crew to railroad officials and to members of the team that fire broke out immediately as a direct effect of the bomb in the first 5 cars behind the locomotive, which were still on the bridge, as well as the 23 cars on the fill section (Photos 49 and 50). The only evidence of fire damage to the bridge consisted of slight irregular charring of a few wooden ties. Table 11 relates to the damaged cars and contents, as told by government railroad officials. It is supplemented by Figure 8.

e. It is felt, after examination of all circumstances, that no fires could have been started within the cars or to the cars themselves from radiant heat of the atomic bomb, primarily because the distance to the train was in excess of 5,800 feet from GZ. The temperature was not high enough nor of sufficient duration to ignite the cars or the contents. The medical supplies in cars 45 through 49 could have combined into many different inflammable mixtures as a result of blast damage. The remaining burned cars were in an area with fires on both sides of the fill. It was therefore evident that those cars were ignited by the fires in the area. The total number of cars—passenger, freight, and electric—damaged at Koi, Yokogawa, and at Bridge 9 is shown in Table 11.

PHOTO 49–XIII. Looking east at damaged freight cars on east end of Bridge 9, 5,800 feet from GZ.

PHOTO 50–XIII. Looking west at damaged freight cars on east end of Bridge 9, 5,800 feet from GZ.

Table 11.—*Damage to Train 377*

[0815 hours, 6 Aug. 1945 on Bridge 9]

No. of car	Type and No.	Station from—	Station to—	Type of goods	Weight (tons)	Damage to car	Damage to goods	Disposition of car
1	Toki 7551	Saruiwa	Nishi-Hachiban			No damage	No damage	Towed into station.
2	Tora 7726	do	do			Totally burned	Totally burned	
3	Wa 1256	Shinagawa	Kokura			do	do	
4	Tsu 514	do	Kurume			do	do	
5	Wa 24922	Namitoi	Nishi-Hachiban			do	do	
6	Tora 22655	Yatsuo	do			do	do	
7	Sumu 486	Fukuda	Moji			do	do	Towed into station.
8	Wamu 8572	do	do			do	do	Do.
9	Wamu 7527	Nakayamatera	Hatsukaichi			do	do	Do.
10	Wamu 53055	Osakawan	Usuki			do	do	Do.
11	Tomu 20002	Hisakawan	do	Metal	18	Severe damage		Left in place.
12	Toki 2705	do	do	Metal tubes	18	do		Do.
13	Toki 1113	Rikuchijohashi	Nishi-Hachiban	Ore		Slight damage		Towed into station.
14	Ho 89	Umeda	Shita	Paper		Totally burned	Totally burned	
15	WA 2409	do	do	do		do	do	
16	Wamu 5008	do	do	do		do	do	
17	Chiki 3625	Anjikawaguchi	Nishi-Hachiban	Machinery	40	No damage	No damage	Towed into station.
18	Chiki 1167	Najikawaguchi	do	do		do	do	
19	Sumu 1702	Nakayamatera	Hatsukaichi	Horseshoes		Totally burned	Totally burned	Left in place.
20	Wa 23169	Umegoro	Moji	Cement		Moderate damage	No damage	Towed into station.
21	Wa 4147	Shibaura	Saishō	Cogwheels		Totally burned	Totally burned	Left in place.
22	Tora 3244	Kameari	Tsukinokawa	Miscellaneous		Severe damage	Burned	
23	Sumu 53148	Akaba	Shita	do		Totally burned	Totally burned	
24	Tora 40771	Fukui	Uedohata			do	do	
25	Toki 3877	Mizoguchi	Minami-Kurume			do	do	
26	To 7624	Umeda	Nakatsu	Buckets		do	do	Do.
27	Tora 41733	do	Ōita	Ironware		do	do	
28	Sumu 2305	Nijō	Moji			do	do	
29	Tamu 1194	Taketoyo	Minami-Nobeoka	Empty		do		
30	Tamu 1200	do	Ōmuda	do		do		
31	Tora 8360	Yatsuo	Nishi-Hachiban	Ironware		do	Totally burned	Do.
32	Sumu 53103	Fukuda	Moji			No damage	No damage	Do.
33	Wamu 27320	Ōsaka	do	Small baggage		do	do	Do.
34	Wa 1891	Inasa Matsu-Shima.	Hakata	Medical supplies	1	Severe damage	do	Do.
35	Tomu 2190	Yasukuratera	Ōmuda	Flour	17	No damage	do	Towed into station.
36	Sumu 10127	Kusatsu	Hida	Miscellaneous	16	Severe damage	do	Do.
37	Tomu 24443	Ishiyama	Kawatana	Torpedoes	18	Slight damage	do	Do.
38	Wamu 25678	Umegoro	Sasebo	Medicines	16	do	do	Do.
39	Sumu 7854	Hoshida	Ōzai	Active charcoal	16	do	do	Do.
40	Wa 17794	Kaizuka	Sasebo	Onions		do	do	Do.
41	Wamu 51651	do	do	do		do	do	Do.
42	Sumu 87	Naka	Tashiro	Aircraft parts	15	do	do	Do.
43	Wamu 28803	Inasa	Minimikurume	Medicine	17	do	do	Left in place.
44	Wamu 25609	Matsumoto	do	do	17	do	do	Do.
45	Wamu 13472	do	Tomitaka	do		Totally burned	Totally burned	
46	Wa 24762	do	do	do		do	do	
47	Sumu 3546	do	do	do		do	do	
48	Wamu 1334	Sasashima	Ōmura	do		do	do	
49	Wa 2870	Takada	Mizumakatera	do		do	do	

SUMMARY

Type of car	Totally burned	Partly burned	Serious damage	Moderate damage	Slight damage	No damage	Total
Steel	10		3	1	4	4	22
Wood	18		2		5	2	27

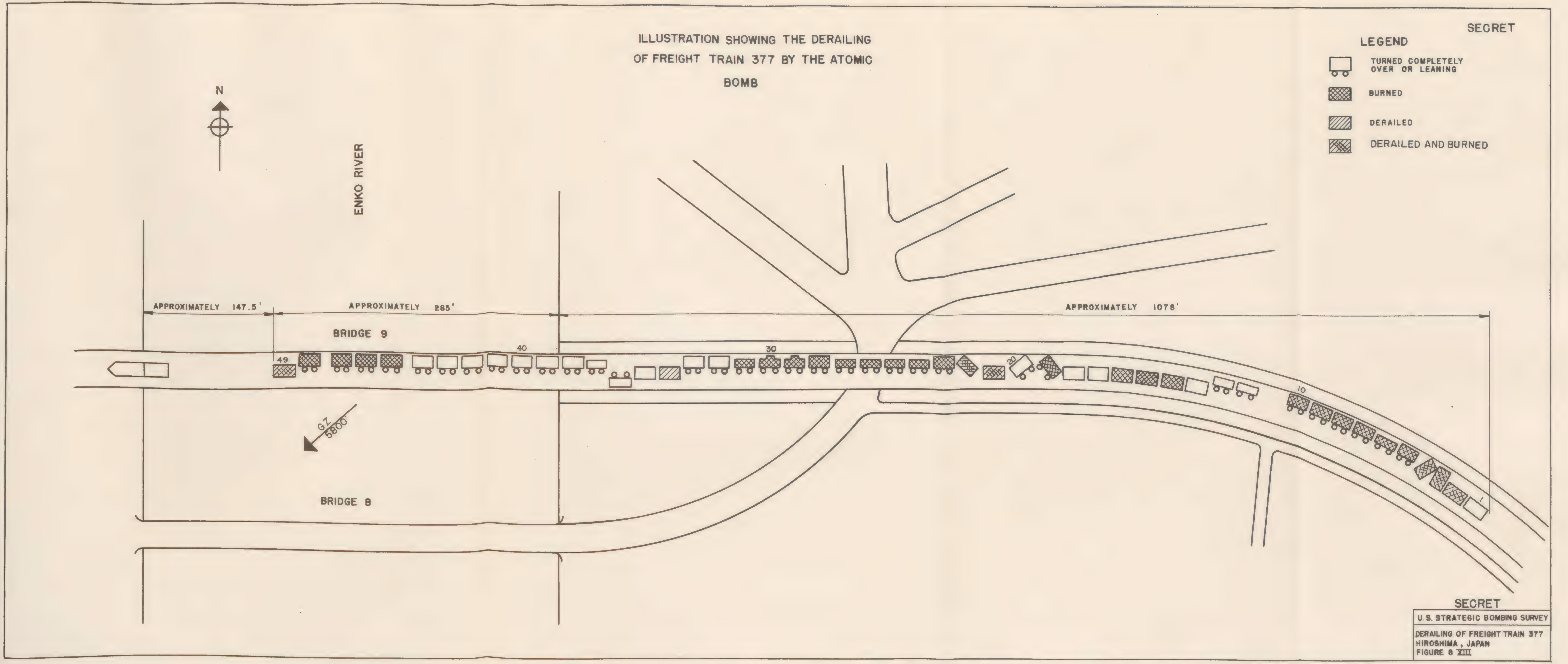

SECRET
ILLUSTRATION SHOWING THE DERAILING
OF FREIGHT TRAIN 377 BY THE ATOMIC
BOMB
LEGEND
TURNED COMPLETELY OVER OR LEANING
BURNED
DERAILED
DERAILED AND BURNED
N
ENKO RIVER
APPROXIMATELY 147.5'
APPROXIMATELY 285'
APPROXIMATELY 1078'
BRIDGE 9
BRIDGE 8
GZ 5800'
49
40
30
20
10
1
SECRET
U.S. STRATEGIC BOMBING SURVEY
DERAILING OF FREIGHT TRAIN 377
HIROSHIMA, JAPAN
FIGURE 8 XIII

*TABLE 12.—*Damage to rolling stock in Hiroshima vicinity*

Station	Type of car	Damage by burning		Damage by blast		
		Total (totally burned)	Heavy (partly burned)	Heavy (severe)	Moderate	Slight
Koi	Passenger car:					
	Steel					
	Wood					
	Freight cars:					
	Steel					
	Wood				1	
Yokogawa	Passenger car:					
	Steel					
	Wood					
	Freight car:					
	Steel					
	Wood	1	7	1	1	2
	Electric cars:					
	Steel	6			1	
	Wood			2	1	2
Bridge 9	Passenger cars:					
	Steel					
	Wood					
	Freight cars:					
	Steel	10		3	1	4
	Wood	18	1	1		5
Total	Passenger cars:					
	Steel					
	Wood					
	Freight cars:					
	Steel	10		3	1	4
	Wood	19	8	2	2	7
	Electric cars:					
	Steel	6			1	
	Wood			2	1	2

*Japanese classification.

As noted in Table 12, car damage at the Koi station, 7,800 feet from GZ, was negligible. The Yokogawa station, however, being 6,000 feet from GZ and in a fire area, received both blast and fire damage.

f. In summarizing the total car damage in Hiroshima and vicinity, table 13 shows the percentage of damage to rolling stock.

TABLE 13.—*Percentage of damage to rolling stock*

Type of car	On hand	Damaged	Percentage
Passenger	91	83	92. 9
Freight	700	91	13. 0
Electric	16	12	75. 0

It is readily seen that passenger and electric cars cars were the more vulnerable, probably because of their construction.

g. In reviewing the damage to the rolling stock by blast, since fires to rolling stock were generally ignited by adjacent burning buildings, a maximum limit of probable damage can be determined. The cars in the classification area within Hiroshima between 8,000 and 10,000 feet from GZ received no damage, but about 50 percent of those in the station area between 5,800 and 6,800 feet from GZ received from heavy to slight damage. In this area some empty cars were overturned. In the Yokogawa station area, 6,000 feet from GZ, the circumstances were the same but no cars were overturned. However, at Bridge 9, which was 5,800 feet from GZ, 41 loaded cars were actually derailed and 15 of the 49 cars were damaged by blast. No information regarding blast damage to the burned cars was received from railroad officials. In the Koi station area, 7,800 feet from GZ, the damage to cars was negligible. From this it can be concluded that the probable maximum limit

of damage for freight cars was approximately 6,800 feet from GZ. This conclusion was based on the low percentage of freight cars damaged, the majority of which were within the 6,800-foot radius. Since passenger cars and electric cars were damaged in a ratio of 93 percent at 6,800 feet and 75 percent at 6,000 feet from GZ, respectively, it can be concluded that the maximum damage limit for these types extends beyond 6,800 feet from GZ. No cars of these types were found beyond that point.

h. There was no damage to the track system or bridges (Photos 51 through 53). The paint on the steel girders of the bridges facing the blast, however, was discolored. All tracks of the Sanyo main line were cleared at 1500 hours on 8 August 1945 and traffic was resumed. Between 6 to 8 August 1945 passengers routed through Hiroshima were compelled to walk between Hiroshima and Koi stations in order to make train connections. Signal systems were inoperative due to damage to the communications office.

i. Traffic dropped off sharply following the attack. Freight tonnage fell from 9,300 tons per month to 5,400 tons per month, requiring only 360 cars. Repairs to rolling stock varied; repairs to locomotives remained at 13 per month; freight cars dropped to 60; while passenger-car repairs were increased to 48 per month. Loss of freight traffic rendered freight-car repair less important.

j. The total cost of damage as estimated by the Government railroad agency on 15 November 1945 was 15,800,000 yen or $3,950,000 at the 4-yen-per-dollar rate of exchange.

k. Of the 8,467 persons employed, 198 were killed, 140 were missing, 934 seriously injured, and 1,195 sustained minor injuries. No information could be obtained for passengers killed or injured during the attack.

4. Comments and Conclusions

a. The damage to the railroad system in Hiroshima as a result of the attack was sufficient to discontinue the services of the system for a short time. The buildings in the station area (Fig. 6) were put out of service entirely by blast and fire, but the buildings in the classification area (Fig. 7) were not damaged sufficiently to disrupt operations. Damage to the electrical substation supplying power caused the disruption, but this condition lasted only until 9 August 1945. The buildings in the station area were, for the most part, of wood construction and compressed into a small area. The fire which eventually reached this area damged all the buildings, but did not damage nearby buildings in the classification area because of the intervening tracks. A fire, started in, or near, this area would have damaged all the buildings more seriously, and railroad service in or through Hiroshima would have been impaired for a longer period of time. It is concluded that dispersal of buildings for necessary repair and storage would be effective protection against an attack of this type. Smaller, complete repair units, independent of each other, would, if dispersed, insure repairs in case of damage to one of the units.

b. Freight cars, with a probable limit of damage at 6,800 feet from GZ, in this instance had a lower rate of vulnerability than passenger cars which had a greater probable limit of damage as shown by the percentage rates in Table 13. Since the trackage system was on the surface there was no effective protection for rolling stock against the attack.

c. The communication office was damaged by fire sufficiently to halt its operation, but the signal towers, being well dispersed, received only superficial blast damage. Since the efficient routing and the safety of trains were entirely dependent on these systems, it was obvious that consideration should have been given to their protection. The benefit of dispersal for protection against fire, as shown in Paragraph 4*a*, has been proved by the lack of fire in the signal towers.

C. ELECTRIC GENERATING AND DISTRIBUTION SYSTEM

1. Summary

a. Cost of Electricity. The Chugoku Electric Co., which supplied the city of Hiroshima with power and light, purchased all its electrical energy from the Nippon Electric Co. at 2.50 sen per kilowatt-hour. The Chugoku Electric Co. in turn sold it to the consumers at 11 sen per kilowatt-hour for lighting, 6 sen per kilowatt-hour for heating, and 4 sen per kilowatt-hour for motor energy. The total consumption per day was 80,000 kilowatt-hours for lighting and 170,000 kilowatt-hours for heating and motor energy.

b. Capacity of System. The Nippon Electric Co. maintained and operated six hydroelectric plants (Table 14) which had a total capacity of 94,200 kilovolt-amperes and one steam-electric plant of 90,000 kilovolt-amperes. These high-tension systems were united at the Hiroshima sub-

PHOTO 51–XIII. Bridge 9. Typical, double-track, railroad bridge, 5,800 feet from GZ.

PHOTO 52–XIII. Typical railroad crossing over road, Bridge 8A, 5,600 feet from GZ.

PHOTO 53–XIII. Bridge 2. Typical, single-track, railroad bridge, 8,500 feet from GZ.

PHOTO 54–XIII. Type D51 series locomotive.

station, rated at 108,000 kilovolt-amperes (Table 17), transmitted power to the Hiroshima Harbor substation (rated at 12,000 kilovolt-amperes) on the west side of Hiroshima, and distributed the electrical energy through 7 substations in Hiroshima having a total capacity of 34,800 kilovolt-amperes (Table 17). The city of Hiroshima was only a part of the area served by the Nippon Electric Co. The Chugoku Electric Co. also operated a steam-electric plant rated at 3,500 kilovolt-amperes to augment the Sendamachi substation. All hydroelectric and steam-generating plants, as well as all substations, are located on Figure 9.

c. Equipment. The generating and transforming equipment of both electrical companies was manufactured by the Nippon Electric Co. The design of all generating and transforming equipment originated with the Westinghouse Electric Co. and the General Electric Co. of the United States. Design data were modified by the Japanese to suit their requirements.

d. Buildings. The office building and substation buildings are classified in Table 15. Buildings included in the building damage section are shown in Table 16.

e. 55- and 110-Kilovolt Transmission System. The Nippon Electric Co. transmitted all electric power from the hydroelectric plants to the substations at 110 kilovolts. Power transmission from the Saka steam plant was maintained at 55 kilovolts; this plant was approximately 4.5 miles from the substation. Both the 55- and 110-kilovolt high-tension lines were overhead systems. They are located on Figure 9.

f. 3.3- and 22-Kilovolt Distribution System. The substations of the Chugoku Electric Co. transformed 22 kilovolts down to 3.3 kilovolts for consumer distribution. The Toyo Industries, Japan Foundry, Hiroshima Electric Railway Co., and the Mitsubishi Shipyard and Heavy Industries, however, having their own substations, received power at 22 kilovolts and transformed it to required voltages. Both overhead and subsurface systems for the 22-kilovolt distribution were employed. The overhead consisted of approximately 95,000 feet of 3-phase system. The subsurface consisted of 95,000 feet of 3-phase system with pole-mounted transformers for feeder distribution. Locations of the 22- and 3.3-kilovolt systems are shown on Figures 9 and 10.

g. Damage to Equipment. The equipment in the substations of the Nippon Electric Co. was undamaged, being 15,000 and 14,300 feet from GZ. Of the 7 substations of the Chugoku Electric Co., the Sendamachi substation and steam-electric plant at 7,700 feet from GZ were heavily damaged by fires which spread to the area. The Otamachi substation, 2,400 feet from GZ, was heavily damaged by blast and fires started by the short-circuited equipment. The Dombara, Misasa, and Eba substations were only slightly damaged at distances from GZ of 5,500 feet and beyond. The damage to the Sendamachi substation would have been greatly reduced by adequate fire protection. The remaining 2 substations were undamaged. Table 18 summarizes the damage.

h. Damage to Buildings. Damage to the buildings of the Nippon Electric Co. and the Chugoku Electric Co. is classified in Table 15. The buildings in Table 15 are classified in the building damage section. Any conclusions therein drawn for the mean areas of effectiveness for buildings will also apply to this section.

i. Damage to 55- and 110-Kilovolt Transmission Systems. The overhead 55- and 110-kilovolt transmission systems were undamaged.

j. Damage to 3.3- and 22-Kilovolt Distribution Systems. Approximately 70 percent of the 3.3-kilovolt overhead and feeder distribution system was damaged by blast and fire. Of the 7,000 poles utilized, 4,000 wood poles and 27 steel-lattice poles were damaged by blast and fire. No concrete poles were damaged. Overhead wires were blown down by blast 8,000 feet from GZ. (Table 19 gives the limit of damage to the poles.) Of the remaining undamaged 30 percent of the distribution system, only 90 percent was usable because some areas beyond the points of damage could not be serviced with electricity due to lack of connections to substations. The damage to the substations of Otemachi and Sendamachi made them inoperative and the areas they serviced were distributed among the other substations. There was no damage to the 22-kilovolt subsurface system.

k. Consumption of Power. By the end of September when the available 5 substations had become operative, 40,000 kilowatt-hours per day were used for lighting and 10,000 kilowatts per day for motors and heating. This was an 80-percent overall reduction in the use of electricity.

l. Cost of Damages. The estimated cost of damages to the Chugoku Electric Co. was 10,000,000 yen, or $2,500,000, at the 4-yen-per-dollar rate of exchange.

m. Personnel Casualties. Of the 600 persons employed by the company, 100 were killed, 100 were injured, and 50 were missing.

2. The System

a. The Chugoku Electric Co. supplied all electrical power to the city of Hiroshima. Although a subsidiary of the Nippon Electric Co., it conducted all business as a separate agency, purchasing its electrical energy from the controlling company. The purchase price of power from the Nippon Electric Co. was 2.50 sen per kilowatt-hour.

b. In order to establish basic rates for the consumption of electric power, separate classifications were established based upon types of appliances (lamps, heaters, and motors) and the scale of rates was established in proportion to the amount of energy used. The cost of energy to residents and industry for each classification was 11 sen per kilowatt-hour for lamps, six for heaters, and four for motors. The average daily consumption of electrical energy was 80,000 kilowatt-hours for lighting, and 170,000 kilowatt-hours for heaters and motors.

c. As shown on Figure 9, the Nippon Electric Co. maintained six high-voltage, hydroelectric generating units and one steam-electric generating plant. Capacities for each unit and the total for all units were as follows:

TABLE 14.—*Generating units*

	Capacity (kilovolt-amperes).
Hydroelectric:	
Uchinashi	24, 750
Doi	10, 000
Shimoyama	18, 750
Kake	15, 700
Kumami	13, 750
Manohira	11, 250
Total	94, 200
Steam-Electric:	
Saka steam plant	90, 000
Grand total capacity	184, 200

The hydroelectric units and the steam-electric unit generated power at approximately 12,000 volts. Because of the distances involved, voltages from the hydroelectric units were transformed up to 110 kilovolts for transmission, while the voltage from the Saka steam plant which was approximately 4.5 miles from the Hiroshima substation was transformed up to 55 kilovolts. The 3-phase delta connections was used in all systems. The Hiroshima substation of the Nippon Electric Co., which was the distribution point for all generat-

TABLE 15–XIII.—*Hiroshima electric distribution system—building data*

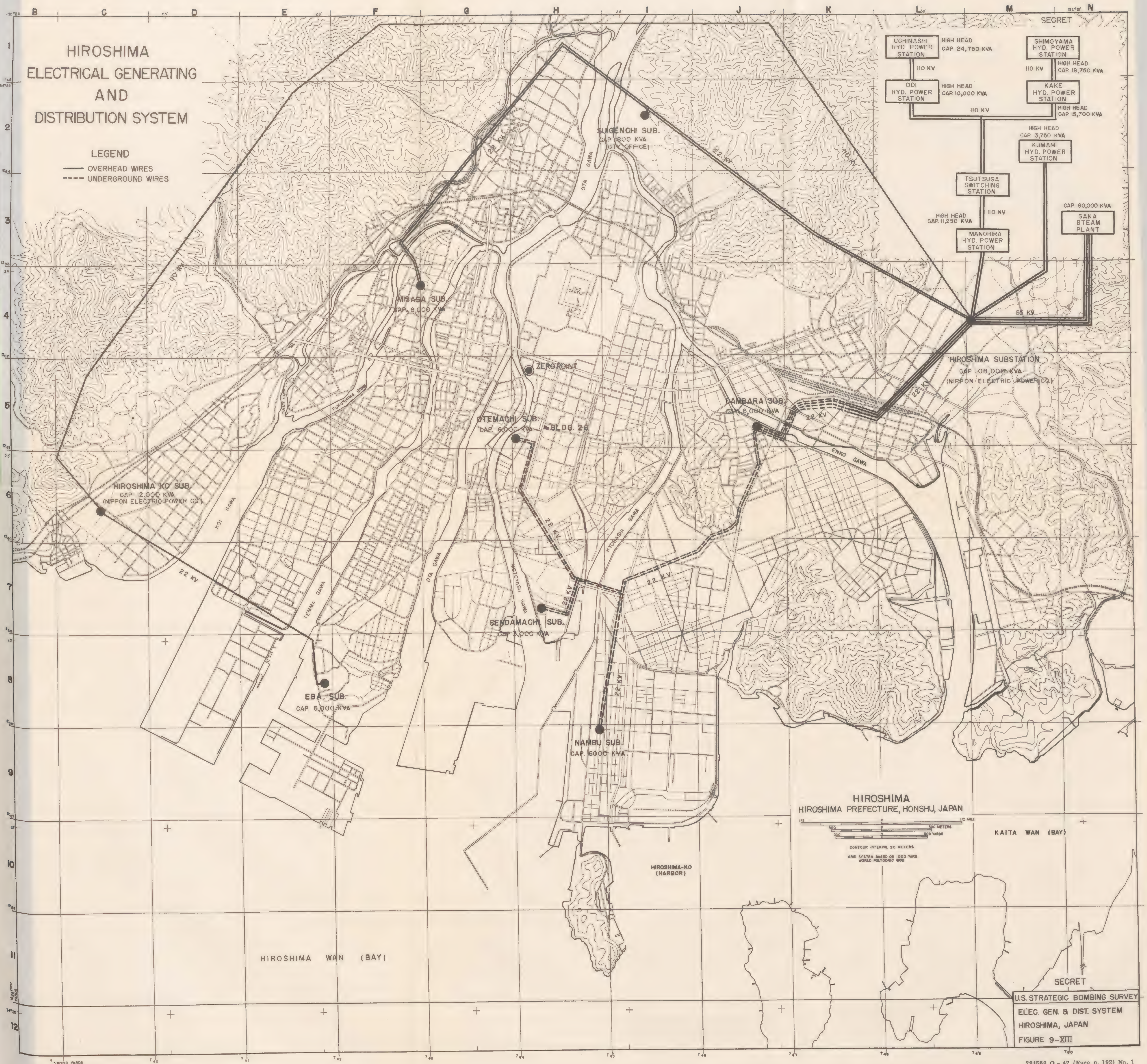
NIPPON ELECTRIC COMPANY BUILDINGS

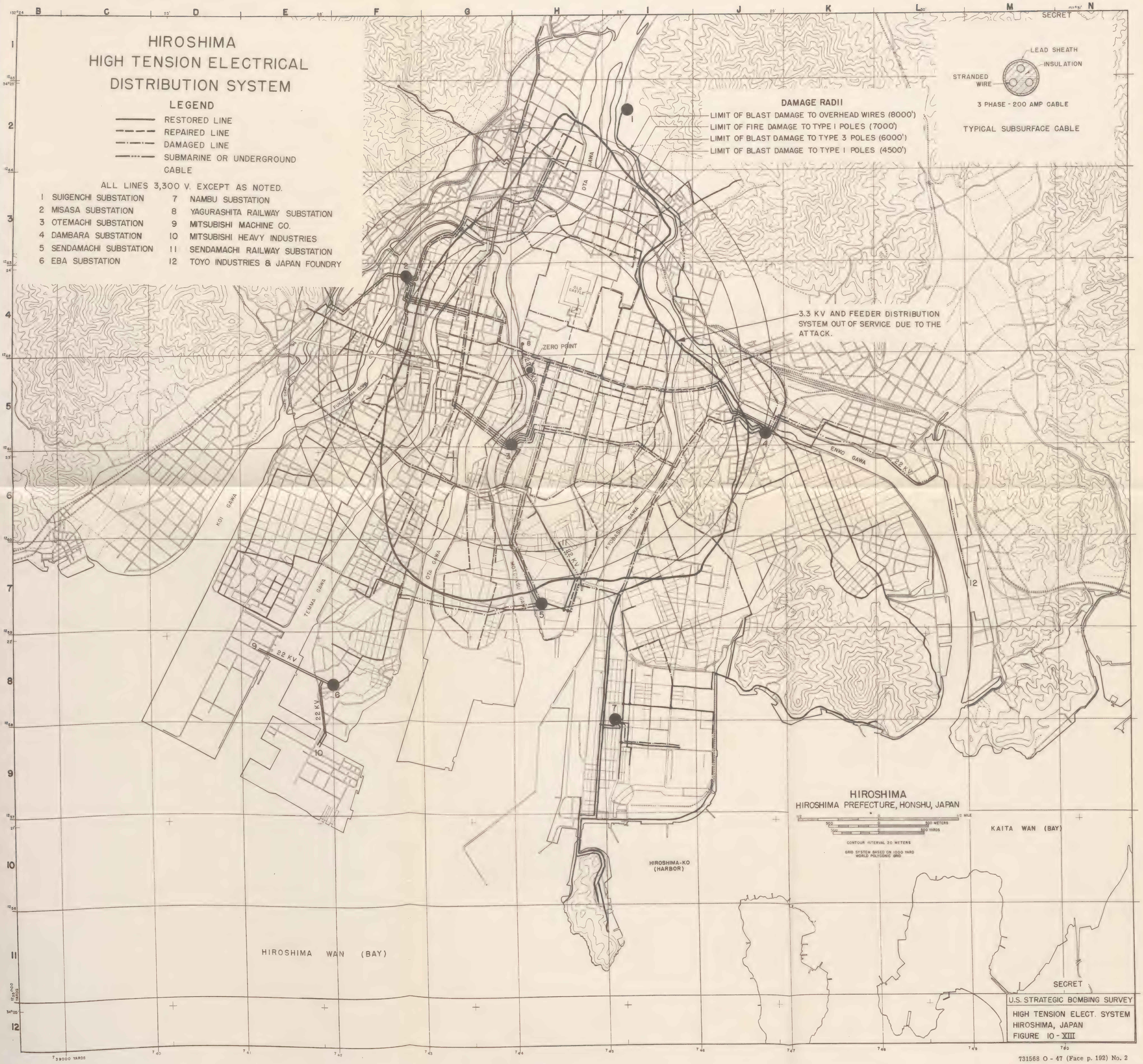
[Areas in thousands of square feet]

Building	Grid	Usage	Type	Plan area	Stories	Building HE-V	Building fire-V	District AZ (feet)	Total floor area	Building damage (floor area): Structural damage: Blast	Structural damage: Fire	Structural damage: Mixed	Superficial damage: Blast	Superficial damage: Fire	Minor damage	Equipment damage: Percent	Equipment damage: Cause
Hiroshima	4M	Substation	S(E-1)	7.5	2/3	V1	R	15, 100	17.5						Slight		
Do	6C	do	S(AZ.3)	2.5	1	V4	C	14, 400	2.5								

CHUGOKU ELECTRIC COMPANY BUILDINGS

Building	Grid	Usage	Type	Plan area	Stories	Building HE-V	Building fire-V	District AZ (feet)	Total floor area	Structural damage: Blast	Structural damage: Fire	Structural damage: Mixed	Superficial damage: Blast	Superficial damage: Fire	Minor damage	Percent	Cause
Dambara	5J	Substation	S(AZ.3)	1.3	1	V4	C	8, 200	1.3						Slight	3	Debris.
Suigenchi	1I	do						9, 200									
Otemachi	5H	do	E-2		3	V3	N	3, 100	4.1				4.1			50	Blast and fire.
Misasa	3F	do	S(AZ.3)	1.6	1	V4	C	5, 900	1.6						Moderate	10	Blast
Sendamachi	7H	Substation						8, 000								5	Blast and fire.
		Turbine building	AZ.3	3.8	1	V4	C	8, 000	7.6				3.8			80	Fire.
		Boiler building	AZ.3	5.0	1	V4	C	8, 000	5.0				5.0			20	Do.
Nambu	9H	Substation	E-1	0.8	2	V4	C	11, 700	1.6						Slight		
Eba	8E	do	D	0.4	1	V4	C	12, 000	0.4				0.2		do	2	Debris.
Office	5H	Office	E-1		4	V1	R	2, 300	20.4	1.6			2.1				


SECRET
HIROSHIMA
ELECTRICAL GENERATING
AND
DISTRIBUTION SYSTEM
LEGEND
OVERHEAD WIRES
UNDERGROUND WIRES
UCHINASHI HYD. POWER STATION
HIGH HEAD CAP. 24,750 KVA
SHIMOYAMA HYD. POWER STATION
HIGH HEAD CAP. 18,750 KVA
DOI HYD. POWER STATION
HIGH HEAD CAP. 10,000 KVA
KAKE HYD. POWER STATION
HIGH HEAD CAP. 15,700 KVA
110 KV
HIGH HEAD CAP. 13,750 KVA
KUMAMI HYD. POWER STATION
TSUTSUGA SWITCHING STATION
HIGH HEAD CAP. 11,250 KVA
MANOHIRA HYD. POWER STATION
CAP. 90,000 KVA
SAKA STEAM PLANT
55 KV
22 KV
SUGENCHI SUB.
CAP. 1800 KVA
(CITY OFFICE)
MISASA SUB.
CAP. 6,000 KVA
ZERO POINT
OLD CASTLE
HIROSHIMA SUBSTATION
CAP. 108,000 KVA
(NIPPON ELECTRIC POWER CO.)
DAMBARA SUB.
CAP. 6,000 KVA
OTEMACHI SUB.
CAP. 6,000 KVA
BLDG. 26
HIROSHIMA KO SUB.
CAP. 12,000 KVA
(NIPPON ELECTRIC POWER CO.)
SENDAMACHI SUB.
CAP. 3,000 KVA
EBA SUB.
CAP. 6,000 KVA
NAMBU SUB.
CAP. 6000 KVA
OTA GAWA
KOI GAWA
TEMMA GAWA
MOTOYASU GAWA
KYOBASHI GAWA
ENKO GAWA
FUKUSHIMA GAWA
HIROSHIMA
HIROSHIMA PREFECTURE, HONSHU, JAPAN
CONTOUR INTERVAL 20 METERS
GRID SYSTEM BASED ON 1000 YARD WORLD POLYCONIC GRID
KAITA WAN (BAY)
HIROSHIMA-KO (HARBOR)
HIROSHIMA WAN (BAY)
SECRET
U.S. STRATEGIC BOMBING SURVEY
ELEC. GEN. & DIST. SYSTEM
HIROSHIMA, JAPAN
FIGURE 9-XIII


SECRET
HIROSHIMA
HIGH TENSION ELECTRICAL
DISTRIBUTION SYSTEM
LEGEND
RESTORED LINE
REPAIRED LINE
DAMAGED LINE
SUBMARINE OR UNDERGROUND CABLE
ALL LINES 3,300 V. EXCEPT AS NOTED.
1 SUIGENCHI SUBSTATION
2 MISASA SUBSTATION
3 OTEMACHI SUBSTATION
4 DAMBARA SUBSTATION
5 SENDAMACHI SUBSTATION
6 EBA SUBSTATION
7 NAMBU SUBSTATION
8 YAGURASHITA RAILWAY SUBSTATION
9 MITSUBISHI MACHINE CO.
10 MITSUBISHI HEAVY INDUSTRIES
11 SENDAMACHI RAILWAY SUBSTATION
12 TOYO INDUSTRIES & JAPAN FOUNDRY
DAMAGE RADII
LIMIT OF BLAST DAMAGE TO OVERHEAD WIRES (8000')
LIMIT OF FIRE DAMAGE TO TYPE 1 POLES (7000')
LIMIT OF BLAST DAMAGE TO TYPE 3 POLES (6000')
LIMIT OF BLAST DAMAGE TO TYPE 1 POLES (4500')
LEAD SHEATH
INSULATION
STRANDED WIRE
3 PHASE - 200 AMP CABLE
TYPICAL SUBSURFACE CABLE
3.3 KV AND FEEDER DISTRIBUTION SYSTEM OUT OF SERVICE DUE TO THE ATTACK.
OLD CASTLE
ZERO POINT
OTA GAWA
FUKUSHIMA GAWA
KOI GAWA
TEMMA GAWA
MOTOYASU GAWA
KYOBASHI GAWA
ENKO GAWA
22 KV
HIROSHIMA
HIROSHIMA PREFECTURE, HONSHU, JAPAN
CONTOUR INTERVAL 20 METERS
GRID SYSTEM BASED ON 1000 YARD WORLD POLYCONIC GRID
HIROSHIMA-KO (HARBOR)
KAITA WAN (BAY)
HIROSHIMA WAN (BAY)
SECRET
U.S. STRATEGIC BOMBING SURVEY
HIGH TENSION ELECT. SYSTEM
HIROSHIMA, JAPAN
FIGURE 10 - XIII

ing units, had a capacity of 108,000 kilovolt-amperes and transformed down to 22 kilovolts for use by the Chugoku Electric Co. The 12,000-kilovolt-ampere substation at Hiroshima harbor was also owned and maintained by the Nippon Electric Co. The location of the generating units and transmission lines are shown on Figure 9. Hiroshima and its vicinity, as serviced by the Chugoku Electric Co., was only a part of the area supplied by the Nippon Electric Co. holdings.

d. The Nippon Electric Co. used the Westinghouse Co. and General Electric Co. type for its generating and transforming equipment with modifications to suit Japanese requirements. All equipment, however, was manufactured by the Nippon Electric Co.

e. The Chugoku Electric Co. received all its electrical energy at 22 kilovolts and transformed it to operating voltages by means of the 7 substations. The Toyo Industries, the Hiroshima Electric Railway Co., the Japan Foundry, the Mitsubishi Heavy Industries, Mitsubishi Shipbuilding Co., and the Mitsubishi Machinery Co., however, received power at 22 kilovolts and transformed it down to the voltages required. There were also approximately 200 small industries which received electrical power at 3.3 kilovolts. Office buildings and dwellings, of which there were approximately 90,000, were supplied at usable voltages.

f. The substation buildings of the Nippon Electric Company and the Chugoku Electric Co. are classified on Table 15. Although buildings were used primarily to protect instruments, the Nambu substation buildings was also used to house the transformers. Transformers for the remaining substation were placed in open areas adjacent to the buildings. Since the Suigenchi substation was without a building it utilized Building 6 of the water-supply system for the protection of instruments. The following buildings will also be found in the Buildings Damage Section.

TABLE 16.—*Buildings classified by Building Damage Section*

Building:	*Building damage section building*
Dambara substation	117
Otemachi substation	16
Sendamachi substation	131A and 131B
Chugoku Electric Co. office	216

g. Table 17 indicates the capacities and voltages of the substations of the Nippon Electric Co. and the Chugoku Electric Co.

TABLE 17.—*Substation capacities*

NIPPON ELECTRIC CO. SUBSTATIONS (TOTAL 2)

Substation	Grid	Capacity (kva)	High side	Voltage	Low side
Hiroshima	5M	108,000	110, 000	------	22, 000
			55, 000	------	22, 000
Hiroshima Ko	6C	12, 000	110, 000	------	22, 000

CHUGOKU ELECTRIC COMPANY SUBSTATIONS (TOTAL 7)

Substation	Grid	Capacity (kva)	High side	Voltage	Low side
Dambara	5J	6, 000	22, 000	------	3, 300
Suigenchi	1I	1, 800	22, 000	------	3, 300
Otemachi	5H	6, 000	22, 000	------	3, 300
Misasa	3F	6, 000	22, 000	------	3, 300
Sendamachi	7H	3, 000	22, 000	------	3, 300
Nambu	9H	6, 000	22, 000	------	3, 300
Eba	8E	6, 000	22, 000	------	3, 300
Total		34, 800			----

According to the electric company engineers, each substation was designed at 6,000 kilovolt-amperes to serve the equivalent area of a 9,800-foot radius. With the exception of the substations at Suigenchi and Sendamachi, all substations were rated at this capacity. Due to the different densities of population and industry, the areas were changed to fit the demands. The Suigenchi substation was installed primarily to serve the city water supply at Ushida, and, being in a sparsely settled area, 1,800 kilovolt-amperes were considered a sufficient capacity. The Sendamachi substation had in addition to the transformer equipment a steam-electric plant rated at 3,500 kilovolt-amperes. Thus the 3,000 kilovolt-amperes of the transformer substation and the 3,500 kilovolt-amperes of the steam-electric plant were combined to establish the required capacity of that area. The transformers and allied equipment, as well as the equipment in the steam-electric Sendamachi substation, were designed, manufactured, and installed by the Nippon Electric Co. Figure 10 shows the location of the 22-kilovolt and 3.3-kilovolt, high-tension lines supplying the city of Hiroshima.

h. The transmission system of electric power was divided into two classes: (1) The overhead system, and (2) the subsurface system. The former, consisting of approximtely 95,000 feet of 3-phase, 22-kilovolt overhead, was placed around the outer rim of the city because of the danger

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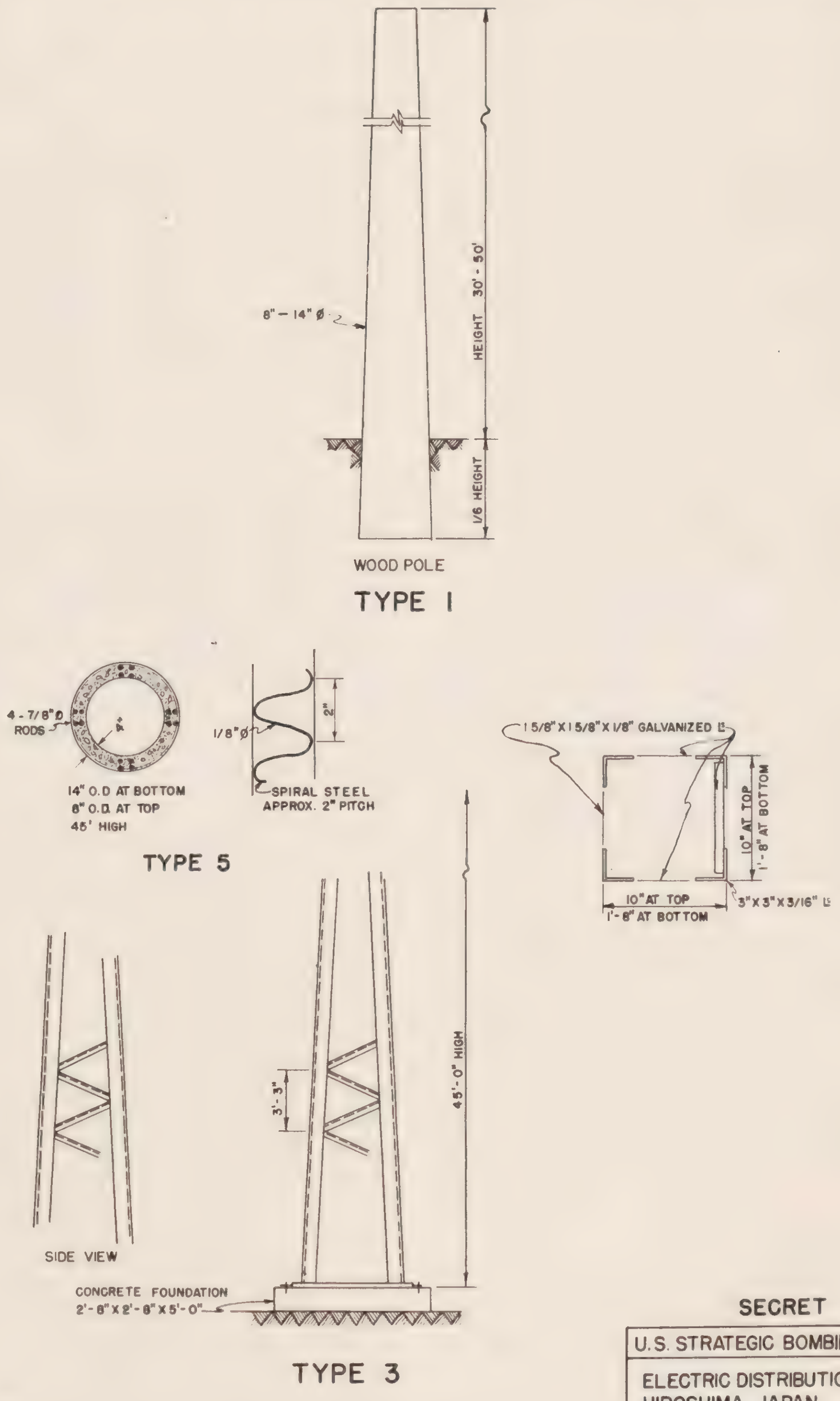
POLES FOR ELECTRIC DISTRIBUTION SYSTEM



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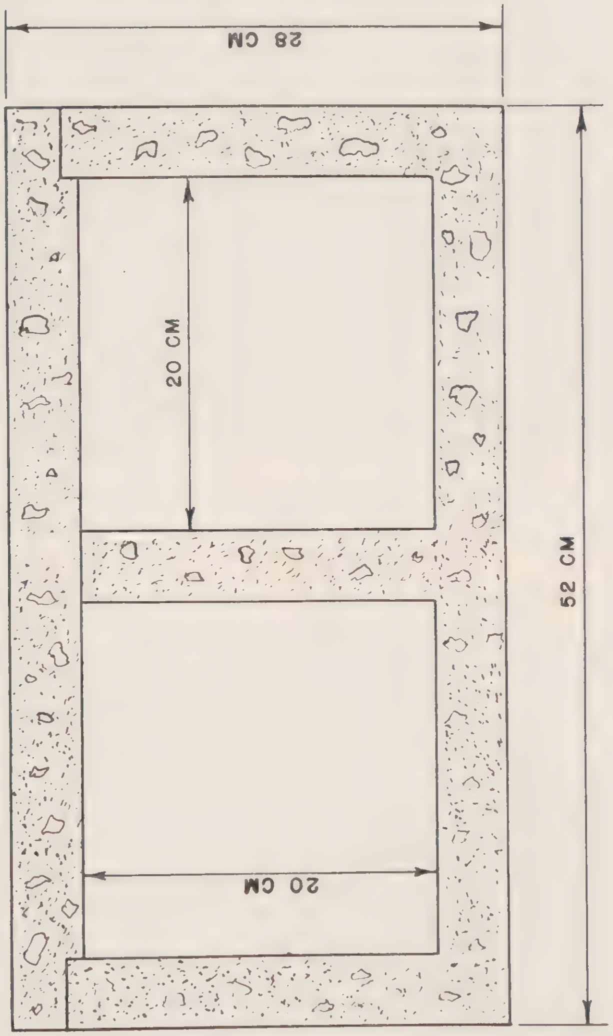
U.S. STRATEGIC BOMBING SURVEY
ELECTRIC DISTRIBUTION POLES HIROSHIMA, JAPAN FIGURE 11-XIII

SECRET

HIROSHIMA

ELECTRICAL GENERATING AND DISTRIBUTION SYSTEM



NOTE:
ALL SIDES AND SLAB 4 CM
REINFORCED CONCRETE.

SECRET

U S STRATEGIC BOMBING SURVEY

ELECTRICAL SYSTEM - DUCTS
HIROSHIMA, JAPAN
FIGURE 12 XIII

connected with a high-tension line of this type. The towers for the 22-kilovolt line were approximately 110 feet high and designed to withstand an overturning moment of 3,000,000 foot pounds. Spacing of the towers was approximately 650 feet. The 3.3-kilovolt system within the city, with all leads to subscribers, required 6,400 Type 1 wood poles, 30 Type 3 steel-lattice poles, and 30 Type 5 concrete poles to complete the system. All poles (Fig. 11) within the city carrying 3.3-kilovolt lines were spaced at 150-foot intervals. All Chugoku Electric Co. substations were interconnected by 3.3-kilovolt lines. Approximately 600 pole-mounted transformers stepped down the voltages for feeder distribution.

i. The subsurface system consisted of 95,000 feet of 200-ampere, 3-phase, lead-sheathed cable. All subsurface cable, including subriver crossings, was laid in reinforced-concrete ducts (Fig. 12), buried 4.5 feet below ground elevation.

j. Attempts to protect transformers from bombing attacks were made by the Japanese at some substations. Earth-filled wood forms varying from 2 to 4 feet in width were erected around the transformers as protection against fragments.

k. The Chugoku Electric Company employed 600 persons for maintenance and operations.

3. Analysis of the Damage

a. The Hiroshima substation (Photos 55, 56, and 57), 15,000 feet from GZ, was undamaged by blast as a direct effect, but the tremendous overload created by the short-circuited damaged electrical equipment in the city of Hiroshima tripped the circuit breakers in this substation and immediately interrupted all electrical service in the Hiroshima area. Officials stated no damage occurred to the equipment and no flash-over was noted. The Hiroshima harbor substation equipment (Photo 58) was undamaged at 14,300 feet from GZ. After investigations by engineers the main substation was in operation the day after the attack, while the Hiroshima harbor substation, although undamaged, was not in operation until 26 August 1945. This delay was due to the difficulty of making inspection in the area in which the 110-kilovolt transmission lines were located.

b. The building of the Hiroshima substation (Photo 57) received only minor damage, while the Hiroshima harbor substation building was undamaged. Table 15 gives the damage classification of the Nippon Electric Co. buildings.

c. The equipment in the substations of the Chugoku Electric Co. at Suigenchi (Photo 59), 9,000 feet from GZ, and at Lambu (Photos 60 and 61), 11,500 feet from GZ, was undamaged by blast or fire. There was no evidence of heavy surges or overloading in these substations, although electrical equipment was damaged in the areas which they supplied. These stations were inoperative due to the power supply cut-off, but were again in service on 9 August 1945. The equipment in the Eba substation (Photos 62 and 63) the Misasa substation (Photos 64 and 65) and the Dambara substation (Photo 66), at 11,800, 5,500, and 7,900 feet, respectively, from GZ, received only slight equipment damage. Two relays in the Eba substation and 4 relays in the Dambara substation were damaged by falling debris and overloading of the circuits. The switchboard, including instruments, wiring, and other panel equipment in the Misasa substation, was damaged by blast and debris. The two relays in the Eba substation were replaced on 11 August 1945, but the station was not in operation until 20 August 1945 because no power was being transmitted from the Hiroshima Harbor substation until that time. The four relays in the Dambara substation were not replaced until September 1945, but the circuits were rewired to shunt out the relays, and the substation was in operation on 9 August 1945. Because of the difficulty of access to the Misasa substation, temporary repairs to enable the substation to operate were not completed until 8 September 1945. The substations at Otemachi (Photos 67 and 68) and Sendamachi (Photos 69, 70, and 71) were sufficiently damaged at 2,400 and 7,700 feet, respectively, from GZ to put them out of service for an indefinite period. The equipment at the Otemachi substation (Photo 68) was dislodged by the effects of the blast and was further damaged by fire caused by short circuits in the equipment. The substation at Sendamachi was heavily damaged by fires originating in the areas adjacent to the substation. Generator coils were burned out and the switchboard totally damaged (Photo 69). Turbine and generator bearings were also damaged. Some distortion to shafting and turbine blades was indicated. Boiler-room damage (Photo 71) was confined to distortion of pipes and metal, but small motors and pumps for collateral equipment were heavily damaged. The transformers (Photo 70) were not damaged, but busbars and insulators received slight damage and all leads to the transforming equipment were totally damaged by blast

PHOTO 55–XIII. Undamaged Hiroshima transformer substation of Nippon Electric Co., 15,000 feet from GZ.

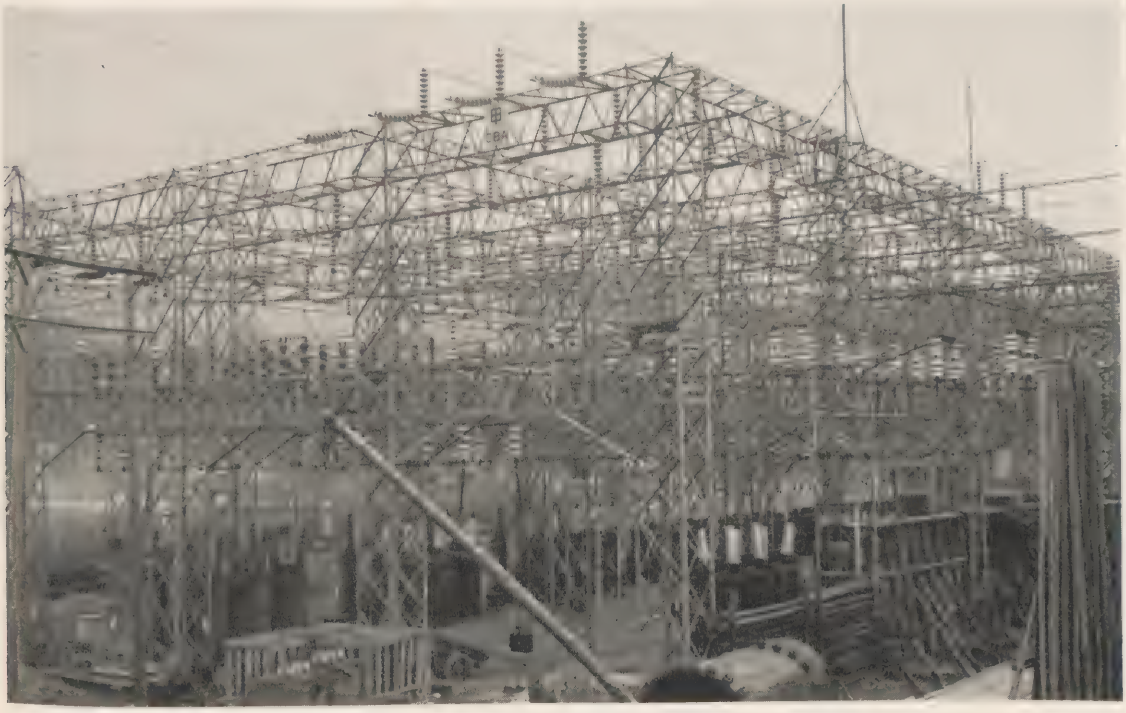


PHOTO 56–XIII. Undamaged Hiroshima transformer substation of Nippon Electric Co., 15,000 feet from GZ.

PHOTO57– XIII. Minor damage to office building. Hiroshima transformer substation of Nippon Electric Co., 15,000 feet from GZ.

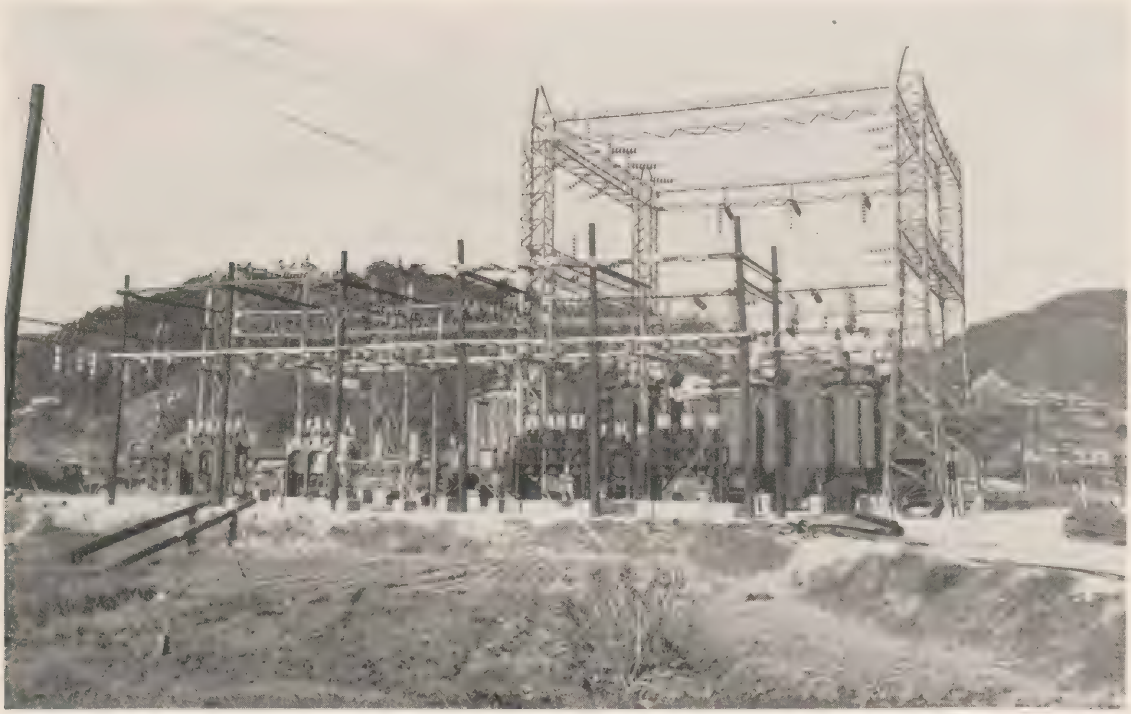


PHOTO 58–XIII. Undamaged Hiroshima Harbor substation of Nippon Electric Co., 14,300 feet from GZ.

PHOTO 59–XIII. Undamaged Suigenchi substation. Note transformer protection, 9,000 feet from GZ.

PHOTO 60–XIII. Undamaged exterior of Nambu substation, 11,500 feet from GZ.

PHOTO 61–XIII. Undamaged interior of Nambu substation.

PHOTO 62–XIII. Eba substation. Building damaged by blast, 11,800 feet from GZ.

PHOTO 63–XIII. Panel of Eba substation.

PHOTO 64–XIII. Blast damage to Misasa substation, 5,500 feet from GZ.

PHOTO 65–XIII. Undamaged busbars and transformers at Misasa substation, 5,500 feet from GZ.

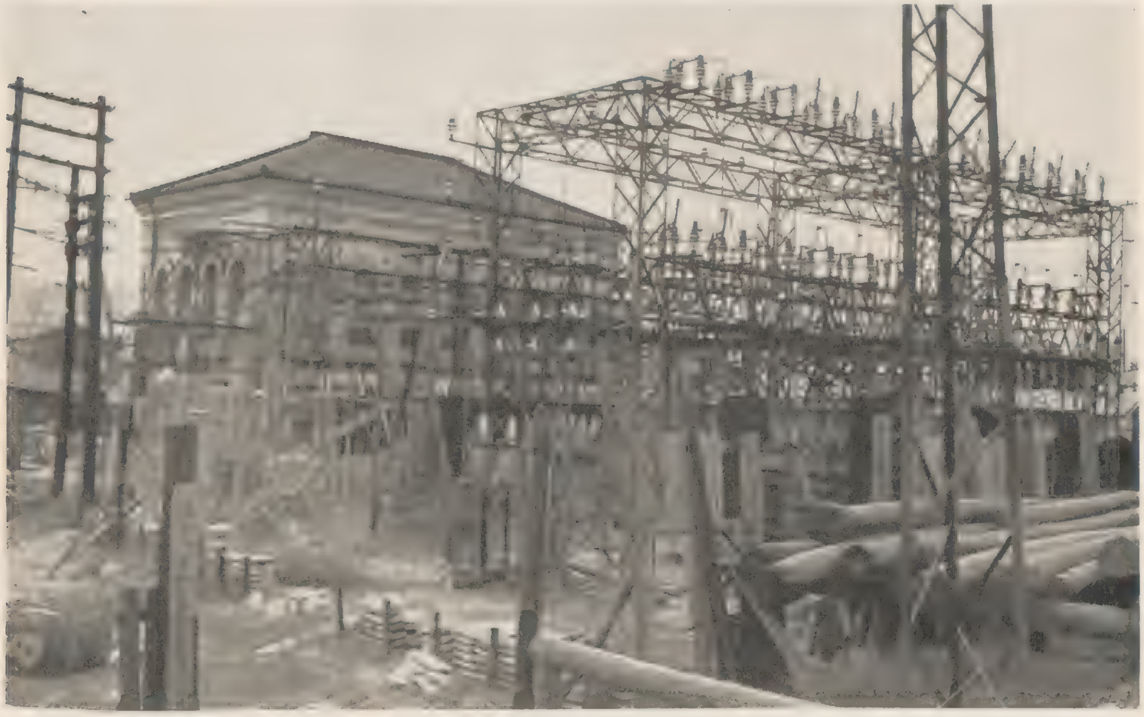


PHOTO 66–XIII. Dambara substation showing undamaged busbars and transformers, 7,900 feet from GZ.

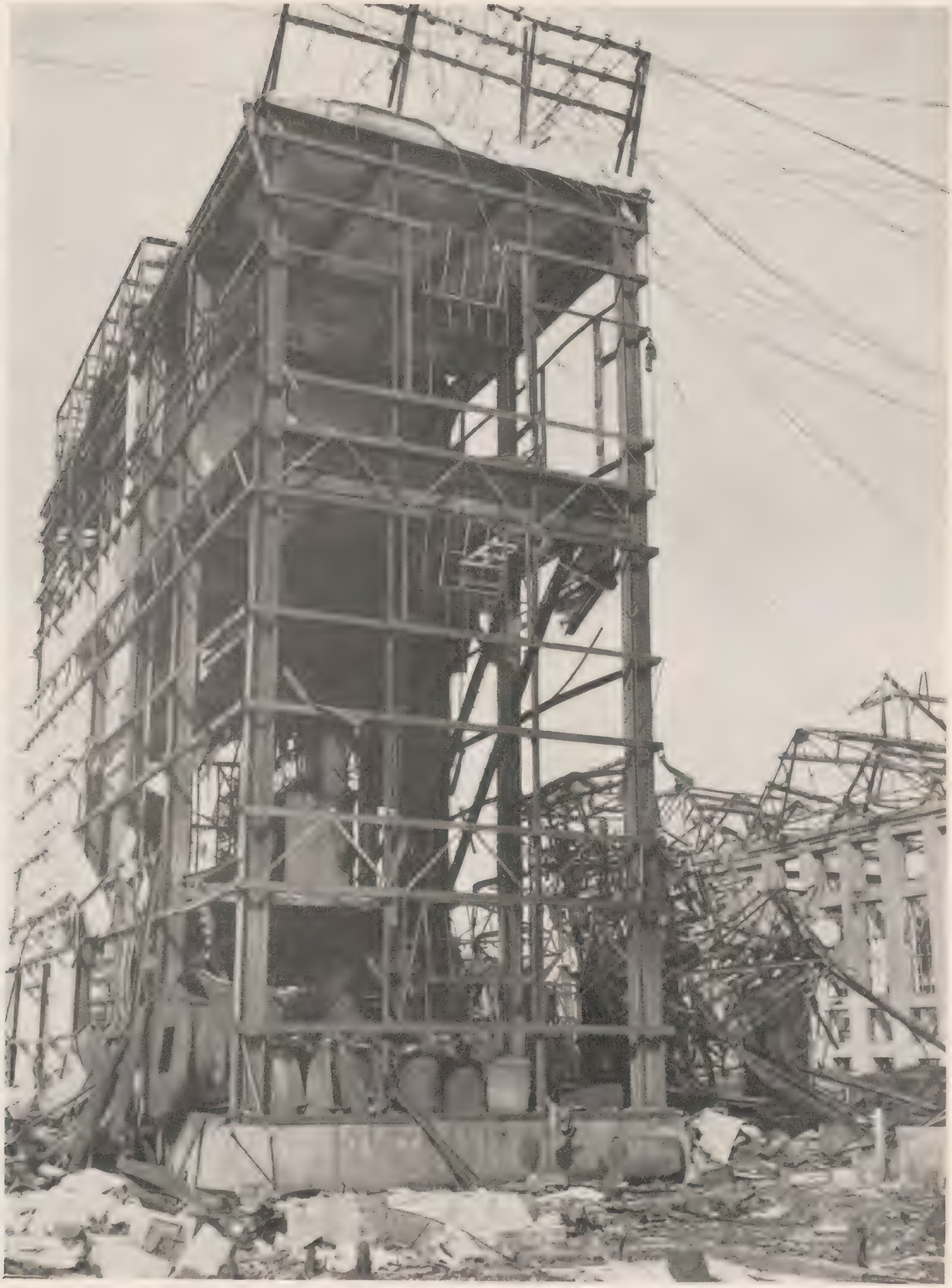


PHOTO 67–XIII. Blast and fire damage to Otemachi substation, 2,000 feet from GZ.

PHOTO 68–XIII. Equipment damage to Otemachi substation, 2,400 feet from GZ.

PHOTO 69–XIII. Turbine and switchboard damage at the Sendamachi substation, 7,700 feet from GZ.

PHOTO 70–XIII. Damage to exterior equipment at Sendamachi substation. Busbars being repaired. Note that out-going lines are down.

PHOTO 71–XIII. Sendamachi substation boiler room damage. Boiler steel warped by heat and collateral equipment damaged by fire.

and fire. Table 18 is a recapitulation of damage to equipment in all substations owned by the Chugoku Electric Co.

TABLE 18.—*Substation equipment damage*

Substation	Grid	Distance from GZ (feet)	Damage type	Cause
Dambara	5J	7, 900	Slight	Debris and overload.
Suigenchi	1I	9, 000	None	
Otemachi	5H	2, 400	Heavy	Blast and fire.
Misasa	3F	5, 500	Slight	Blast.
Sendamachi				
Turbo-Generators	7H	7, 700	Heavy	Fire.
Boilers	7H	7, 700	Slight	Do.
Transformers	7H	7, 700	do	Blast and fire.
Nambu	9H	11, 500	None	
Eba	8E	11, 800	Slight	Debris and overload.

The engineers of the Chugoku Electric Co. were unable to give the approximate date when the Otemachi or Sendamachi substation would be repaired and resume operations. Although the damage to the tranformers and collateral equipment at the Sendamachi substation was slight, little or no effort was expended in placing the system in operation.

d. Of the 7 substations and one office building of the Chugoku Electric Co., the office building (Photo 72) alone received structural damage by blast. The Eba (Photo 62), the Otemachi (Photo 67), Misasa (Photo 64), and Nambu (Photo 60) substations were damaged to a minor degree only. The Suigenchi substation (Photo 59) had no attached building but depended on Building 6 of the purification plant (Part E of this section) for housing its recording equipment. Damage classification of all substation buildings is given in Table 15.

e. The substations of the Toyo Industries, Japan Foundry, and the Mitsubishi Shipyards and Industries were undamaged, being at distances greater than 15,000 feet from GZ. The damage to the substations of Hiroshima Electric Railway Co., Inc., will be found in Part A of this section.

f. The 110-kilovolt, high-tension lines of the Nippon Electric Co. were undamaged, the nearest point of these lines being 11,000 feet from GZ. There was neither blast nor fire damage to the 22-kilovolt overhead transmission lines (Photo 73) of the Chugoku Electric Co., although the 22-kilovolt overhead lines which supplied the Misasa substation (Photo 74) were only 5,700 feet from GZ. Approximately 70 percent of the 3.3-kilovolt overhead transmission lines and feeders, including pole-mounted transformers, was damaged by blast and fire. (NOTE.—In the following pages, photos with an asterisk (*) will be found in Part A, and those marked with a number sign (#) will be found in Part C of Sec. XIII.) Of the 6,400 wood poles (Type 1), 500 were broken by blast (Photos *16, 76, 77, 78, 79, 80, 81, 82, and 84), and 3,500 were burned (Photos 82, 85, 87, and 88). Of the 30 steel-lattice poles (Type 3) 6,000 feet from GZ, 27 were damaged by blast (Photos *17, *19, *22, 76, and 77), having been bent at the base. No concrete poles (Photo *23) were damaged, the nearest concrete pole being 6,000 feet from GZ. Overhead transmission wires were found parted and down 8,000 feet from GZ as a result of blast (Photos *86 and *88). The limits of damage to the types of poles of the Chugoku Electric Co. are shown on Table 19.

TABLE 19.—*Pole damage limit*

Pole type	Material	Damage		
		Blast (feet)	Burned (feet)	Tilted (feet)
1	Wood	4, 500	7, 000	7, 500
3	Steel lattice	6, 000		
5	Concrete			

g. Of the 70 percent of the 3.3-kilovolt overhead lines and feeders damaged, it was estimated that 10 percent could be salvaged for reuse with the exception of the pole-mounted transformers (Photo 75), which were totally damaged, requiring 100 percent replacement. The remaining 30 percent of the overhead was only 90 percent operative because the overhead transmission beyond the points of damage could not be supplied with electricity due to the heavy damage in the Otemachi and Sendamachi substations. The 3.3-kilovolt lines in these areas which were undamaged were divided among the adjacent substations, and supplied with power by shunting around the Otemachi and Sendamachi substations and interconnecting with the other available substations. Figure 10 shows the extent of damage and replacement of overhead.

h. The subsurface 22-kilovolt transmission system was undamaged and consequently power could be supplied immediately to the substations which were operative. The 22-kilovolt subsurface lines supplying undamaged facilities from the damaged substations were shunted around those substations and supplied by others.

PHOTO 72–XIII. Blast damage to the office of the Chugoku Electric Co. (Bldg. 26), 2,300 feet from GZ.

PHOTO 73–XIII. Conversion from overhead transmission system to subsurface system. Undamaged at 9,500 feet from GZ.

PHOTO 74–XIII. High tension tower, 6,500 feet from GZ, undamaged.

PHOTO 75–XIII. Pole-mounted transformer damaged by fire, 200 feet from GZ.

PHOTO 76–XIII. Steel lattice and wood pole 2,000 feet from GZ.

PHOTO 77–XIII. Steel lattice and wood pole 2,000 feet from GZ. Framing members of Bridge 30A also damaged at this distance.

PHOTO 78–XIII. Wood poles 3,000 feet from GZ.

PHOTO 79–XIII. Wood poles 3,000 feet from GZ.

PHOTO 80–XIII. Wood pole down at 4,000 feet from GZ.

PPOTO 81–XIII. Broken wood pole 4,500 feet from GZ.

PHOTO 82–XIII. Burned poles 4,500 feet from GZ.

PHOTO 33–XIII. Broken and replaced wood pole 4,500 feet from GZ.

PHOTO 84–XIII. Broken wood pole at 4,500 feet from GZ.

PHOTO 85–XIII. Burned poles at 5,500 feet from GZ. This area was 40 percent built up Burning of area resulted also in burning of poles.

PHOTO 86–XIII. Tilted wood poles 7,000 feet from GZ. Note flash burns and severe tilt away from blast.

PHOTO 87–XIII. Charred poles 7,500 feet from GZ.

PHOTO 88–XIII. Scorched poles and wire down 8,000 feet from GZ.

i. By the end of September 1945, when all available substations were in operation 40,000 kilowatt-hours per day for lamps and 10,000 kilowatt-hours per day for motors and heaters were being consumed. This indicated a 50-percent reduction in the use of lamps and 94-percent reduction in the use of heaters and motors, or an 80-percent over-all reduction in the use of all electrical facilities.

j. The estimated cost of damage to the electrical power and light facilities on 15 November 1945 was 10,000,000 yen, or $2,500,000 at the 4-yen-to-a-dollar rate of exchange.

k. Of the 600 employees of the Chugoku Electric Co., 100 were killed, 100 injured, and 50 missing.

4. Recommendations and Conclusions

a. The electrical generating, transforming, and transmission equipment of the Nippon Electric Co. and the Chugoku Electric Co. was on a standard comparable to that used in the United States. This was not unexpected, since the design data for the equipment of these Japanese firms were supplied by the leading electrical companies of the United States. Some modifications in the equipment, however, were made by the Japanese. With the exception of the Otemachi and Sendamachi substations, the substation equipment successfully withstood the effects of the attack. Had fires not reached the Sendamachi substation at 8,000 feet from GZ, it is believed that damage would have been confined to equipment in the same degree as that at the Dambara substation at 8,200 feet from GZ (Table 15). If adequate fire protection had been maintained in the Sendamachi substation, damage would have been slight. Auxiliary pumps, however, would have been necessary to protect these vital utilities in case of power failure. Fires in the Otemachi substation were caused by the short-circuited equipment. Only one substation which amounted to 15 percent of the substation system was put out of service by blast and resulting short-circuit fires. The remaining substations, having suffered only slight equipment damage, were operative wtihin a short time. From these facts it is considered that with modern equipment and normal fire protection 85 percent of the substations would be immune to an attack of this type.

b. With the exception of the office building of the Chugoku Electric Co., which was structurally damaged by blast, the substation buildings, being well dispersed, received only damage extending from superficial to slight, as shown on Table 15. It appears evident in this case that dispersal of substations was adequate protection, but these conditions could be improved by the elimination of combustible material in or near the structures.

c. The 110- and 22-kilovolt overhead transmission systems received no blast or fire damage, a terminal of a 22-kilovolt line being at the nearest point, 5,700 feet, from GZ. The 3.3-kilovolt lines with the connecting feeders were particularly vulnerable to an attack of this type, and approximately 70 percent of the transmission lines were damaged. The Type 1 poles were damaged by blast up to 4,500 feet from GZ and by fire up to 7,000 feet from GZ. The Type 3 poles were vulnerable to 6,000 feet from GZ. Since there was no Type 3 poles farther than this from GZ, the limit at which they could withstand the blast could not be determined. Inasmuch as only 10 percent could be salvaged from the 70-percent damage, a considerable amount of replacement and repair to an overhead system carried on Types 1 and 3 poles could be anticipated from an attack of this sort.

d. Since the subsurface lines buried 4.5 feet below ground elevation were undamaged, all 22-kilovolt lines were available for use. If costs were not exorbitant, a subsurface system for lines of lower voltages would be the best protection.

D. TELEPHONE COMMUNICATIONS SYSTEMS

1. Summary

a. Traffic. The Bureau of Telephones of the governmental communications department administered and operated all telephone communications within and through the city of Hiroshima which was divided into two districts, the Central District, which maintained a manually operated system and had 5,500 subscribers, and the Western District, which maintained a dial system with 3,400 subscribers. The average local traffic per month was 3,240,000 calls. Long-distance calls, averaging 435,000 per month, were routed through the central district. Telephones and equipment were of Western Electric design and Japanese manufacture.

b. Transmission System. The transmission system consisted of both overhead and subsurface lines. The Central District (Fig. 13) maintained 104,790 feet of overhead cable carried by 4,958 poles, and 30,232 feet of conduit-encased, subsurface cable. The Western District maintained 53,660 feet of overhead cable carried by 2,493 poles,


HIROSHIMA
TELEPHONE COMMUNICATION
SYSTEM
LEGEND
OVERHEAD
UNDERGROUND
INTERURBAN UNDERGROUND
SUB-RIVER CROSSINGS
APPROXIMATELY 4.00 FEET
UNDER BOTTOM
P PAIR OF WIRES PER CABLE
DAMAGE RADII
LIMIT OF BLAST DAMAGE TO OVERHEAD CABLES (8000')
LIMIT OF FIRE DAMAGE TO TYPE I POLES (6500')
LIMIT OF BLAST DAMAGE TO TYPE I POLES (4500')
SECRET
ZERO POINT
WESTERN EXCHANGE
CENTRAL EXCHANGE
LONG DISTANCE RELAY STATION
TO KURE
TO IWAKUNI
TO FUKUOKA
TO TOKYO
KUBE
ENKO GAWA
KOI GAWA
TEMMA GAWA
OTA GAWA
HIROSHIMA
HIROSHIMA PREFECTURE, HONSHU, JAPAN
CONTOUR INTERVAL 20 METERS
KAITA WAN (BAY)
HIROSHIMA-KO
(HARBOR)
HIROSHIMA WAN (BAY)
SECRET
U.S. STRATEGIC BOMBING SURVEY
TELEPHONE SYSTEM
HIROSHIMA, JAPAN
FIGURE 13-XIII

and 9.770 feet of conduit-encased cable. All subsurface cable was buried 4 feet below ground elevation. Intersections occurred at manholes, of which there were 223. Because of the number of branches of the Ota River, 18 bridge cable crossings and 9 subriver crossings were necessary. Subriver cable was buried 4 feet below river bottom.

c. Building Damage. The buildings of the Central and Western District exchanges are treated in the building damage section and are found in Table 23. The initial damage to the equipment in both exchanges was by blast. Fires from short circuits totally damaged all equipment in the Central District exchange, but new, enclosed-type equipment in the western district reduced short-circuit fire damage to 50 percent. All telephone communications were disrupted.

d. Overhead Transmission System Damage. Approximately 80 percent of the overhead system was damaged by blast and fire; 97,280 feet of cable and 4,551 wood poles being damaged in the Central District, and 51,280 feet of cable and 2,293 wood poles in the Western District. A 10-percent salvage value was estimated. Wood poles were damaged by blast at 4,500 feet from GZ and burned at 6,500 feet. Cable was stripped from hangers at 8,000 feet.

e. Bridge Damage. There was no damage to the conduits and manholes carrying the subsurface system. Damage to Bridges 6, 13A, 21, 24, and 29, however, as well as damage to cable exit points on conversion to overhead, put approximately 80 percent of the subsurface system out of service. By 15 August 1945, 35 pairs of subsurface cable had been repaired and were available for use. All bridge data are covered by the Bridge Damage Section, and any conclusions drawn by that section for means areas of effectiveness for bridge will apply also for this section.

f. Subsurface Transmission Damage. The subsurface system at 4 feet below ground elevation would have been intact if it had not been exposed to exterior damage at bridge crossings and exit points to the overhead system. Approximately 80 percent of the subsurface system was put out of service, but the majority of the cable was salvageable.

g. Cost of Damage. The estimated cost of damage to telephone communications by the attack was approximately 10,000,000 yen, or $2,500,000 at the 4-yen-to-a-dollar exchange rate.

h. Casualties. Of the 900 personnel employed, 350 were killed, injured, or missing.

2. The System

a. All telephone communications in Hiroshima were under strict government supervision. The telephone service was divided into two types, the dial and manually operated systems. The Central District, all that portion of Hiroshima east of the Ota River, utilized the manually operated system, having 5,500 subscribers serviced through Exchange Building 43. The Western District utilized the dial system, having 3,500 subscribers placing calls through Exchange Building 85. In addition, there was a relay station for interurban service through Hiroshima. The local telephone traffic within the city for both types of exchange averaged 3,240,000 calls per month. All long-distance traffic was routed through the Central District exchange and via the Western District exchange, if the call was placed or taken in that district. The long-distance traffic averaged 435,000 calls per month. The locations of the telephone-exchange buildings in the Central and Western districts of Hiroshima City, listed as Buildings 43 and 85, respectively, by the Building Damage Section, and all overhead and subsurface transmission systems of the Bureau of Telephones, Governmental Communications Department, are indicated on Figure 13.

b. The manually operated telephonic equipment in the central exchange building was of the Western Electric Co. type, manufactured by the Oki Electric Co. Installation of equipment was completed in 1920 by the same company. The dial telephone equipment in the Western Exchange Building was also based on the Western Electric Co. type and manufactured by the Oki Electric Co. which completed the installations in February 1940. All telephones were of Western Electric manufacture. Conversion equipment for both exchange buildings was of Japanese design and manufacture.

c. As shown on Figure 13, both overhead and subsurface transmission systems were used. The number of pairs and length for each circuit are shown in Table 20. (One pair of wires was necessary for each telephone connection.)

The length of pairs was measured to the city limits only. Standard, lead-sheathed telephone cable was used in both overhead and subsurface systems. Of the 4,958 poles in the Central District, 4,951 were wood, 2 were steel, and 5 were concrete. The

TABLE 20.—*Overhead and subsurface transmission cable*

Number of pairs per cable	Central district		Western district	
	Subsurface (feet)	Overhead (feet)	Subsurface (feet)	Overhead (feet)
1,200	4, 532		2, 869	
800	7, 476		1, 624	
600	7, 696		3, 633	
400	6, 194		1, 358	
200	1, 463	374	258	
100	970	53, 328	32	26, 445
50	1, 901	32, 944		18, 926
25		13, 773		6, 818
15 and under		4, 462		1, 477

Western District had wood poles only, numbering 2,493. Figure 14 illustrates details of the types of poles used. In designing the telephone system the Bureau of Telephones favored the use of large cables for subsurface transmission and small cables for the overhead system to facilitate connections to subscribers. Various types of ducts or conduits were employed as indicated in the following table:

TABLE 21.—*Types of conduit*

Conduit type	Mains (feet)	Laterals (feet)	Outside diameter (inches)	Wall thickness (inches)
Half-iron, half-steel	18, 761	53, 201	2. 953	0. 355
Cast-iron	5, 443	6, 592	2. 953	. 315
Asbestos-cement	1, 200	2, 800	2. 953	. 315
Tile ducts	1, 143	5, 401	Varies	Varies

d. All subsurface conduit was buried 4 feet below ground elevation. Intersections of cables in the subsurface system occurred at manholes which totaled 223. Of these, 10 were brick and 213 were reinforced concrete. Figure 15 shows the construction of both types. The brick manholes were built when the telephone system was first started, but were later discarded in favor of the reinforced-concrete type. The manholes were not waterproofed nor did they have drains. Because of the numerous branches of the Ota River passing through Hiroshima, 27 crossings were necessary for the local and long-distance circuits. Of these, 18 were bridge crossings and 9 were subriver crossings, one of the latter being a local circuit, and the others, long-distance lines as shown on Figure 13. Conduits were buried 4 feet below river bottom. Table 22 gives lengths of bridge cable crossings.

Conduit-protected cable was attached to some steel and concrete bridges, but no conduit was provided for cable on timber bridge crossings.

e. There were approximately 900 persons employed by the Bureau of Telephones for office work and maintenance operations.

3. Analysis of Damage

a. The Central and Western Districts Exchange Buildings were listed as Buildings 43 (Photo 89) and Building 85 (Photo 91), respectively, by the Building Damage Section, and the damage analysis for these buildings is contained in that

TABLE 22.—*Cable over-crossings*

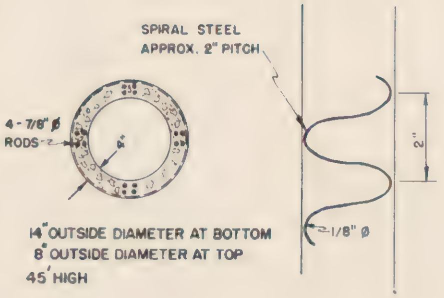
Bridge	Grid	Length (feet)	Type of bridge	Number of pairs per cable	Protection	Local or interurban
4	5J	276	Concrete	800	Conduit	Local.
5	5J	248	do	960	do	Do.
6	4I	266	Timber	100	None	Do.
8	4I	518	Concrete	200	do	Do.
12	5I	208	Plate girder	960	Conduit	Do.
13A	5I	307	Timber	1, 800	None	Do.
16	6I	316	Concrete	100	Conduit	Interurban.
17	7H	544	Plate girder	1, 400	do	Local.
19	6G	259	Concrete	100	do	Interurban.
21	5H	295	Timber	1, 000	None	Local.
22	5H	164	Plate girder	1, 200	Conduit	Do.
24	4G–H	398	do	800	do	Do.
27	3G	200	Steel arch	600	do	Do.
29	5G	263	Pin-connected truss	2, 000	do	Do.
31	6H	358	Concrete	100	do	Interurban.
33	6F	410	do	100	Overhead	Local.
37	5G	180	Plate girder	2, 000	Conduit	Do.
48	4E	240	do	600	do	Do.

SECRET

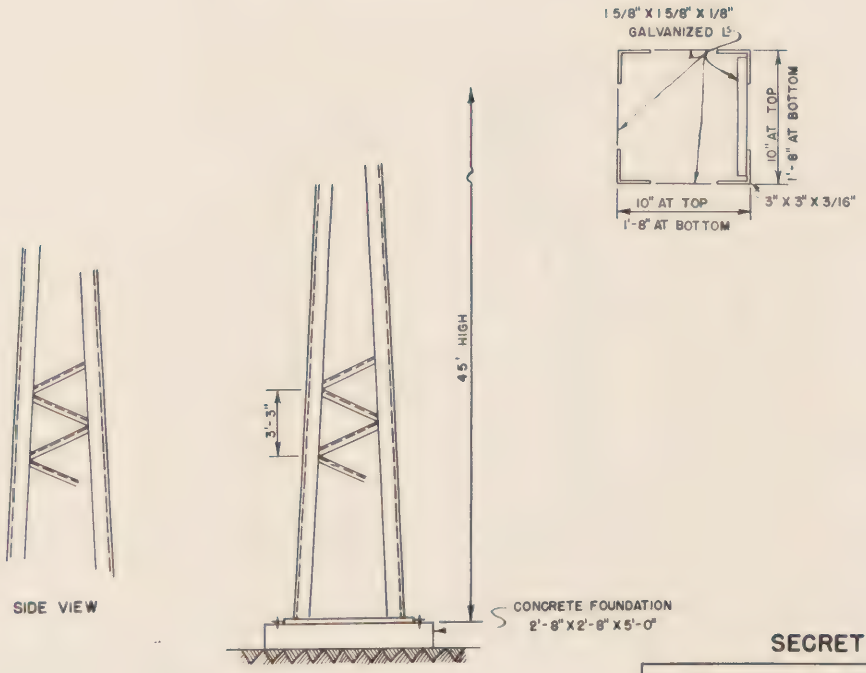
POLES FOR TELEPHONE COMMUNICATION

WOOD POLE

TYPE I



TYPE 5



TYPE 3

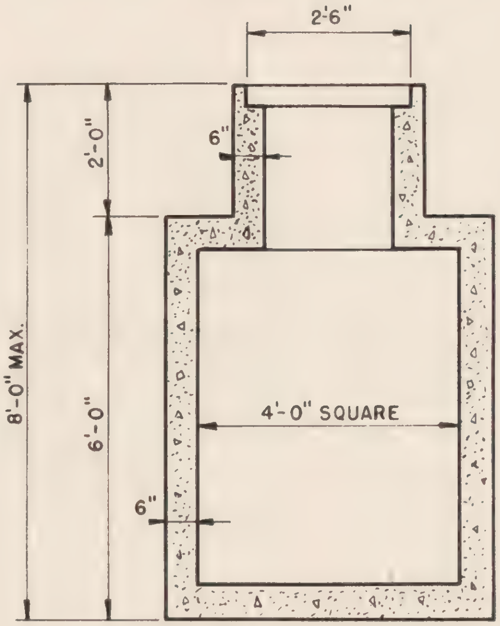
SECRET

U.S. STRATEGIC BOMBING SURVEY

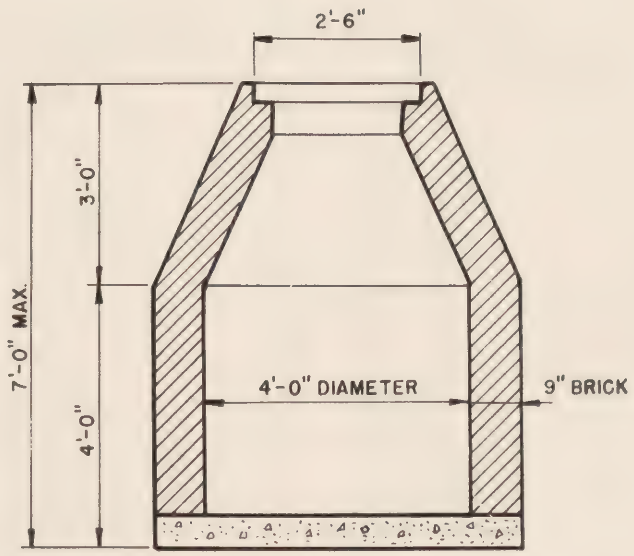
TELEPHONE POLES
HIROSHIMA, JAPAN
FIGURE 14-XIII

SECRET

TELEPHONE COMMUNICATION SYSTEM MANHOLES



STANDARD SQUARE CONCRETE MANHOLE



STANDARD ROUND BRICK MANHOLE

SECRET

U.S. STATEGIC BOMBING SURVEY
TELEPHONE SYSTEM MANHOLES
HIROSHIMA, JAPAN
FIGURE 15 XIII

TABLE 23–XIII.—*Hiroshima telephone communications system—building data*

[Areas in 1,000's of square feet]

Building	Grid	Usage	Type	Plan area	Stories	Building HE-V	Building Fire V	Distance AZ (feet)	Total floor area	Building damage (floor area)						Equipment damage	
										Structural damage			Super. damage		Minor damage	Percent	Cause
										Blast	Fire	Mixed	Blast	Fire			
43	5H	Telephone exchange	E1	-----	2/3	V1	R	2,800	36.1	------	-----	-------	------	------	Severe	100	Fire.
85	4G	do	E1	------	3	V1	R	3,800	14.2	------	-----	-------	------	------	Moderate	50	Mixed.

section. Table 23, however, shows the extent of damage to each building.

b. The equipment in the Central District (Photo 90) and the Western District (Photo 92) Exchange Buildings, which were 2,800 and 3,800 feet, respectively, from AZ, was initially damaged by blast. Short circuits from damaged equipment started fires that totally damaged the equipment in the Central District Exchange Building. Eyewitnesses stated that the equipment was afire immediately after the explosion, corroborating a statement made by the chief engineer of the Bureau of Telephones. Since the equipment was on the opposite side of the building facing AZ, adequate protection from radiant heat was afforded by the concrete slabs. It was therefore concluded that short circuits were the cause of the fire, which was in agreement with the Japanese. The equipment in this exchange was of the old, open type and burned freely; the Western District Exchange equipment, being of recent manufacture, was enclosed and the damage due to blast and short circuit fires was reduced to 50 percent, but the damage was sufficient to halt all telephone communications. Blast and fire destroyed approximately 7,000 telephones.

c. The greatest damage to the telephone transmission system was in the overhead section (Photos *16, *17, *18, *22, *23, and 94 through 98). The majority of poles, being wood, were downed by blast or were consumed by the fire that followed. Lead-sheathed cables were totally damaged by fire, being consumed up to the point of entry of the subsurface system (Photo 93). Wood poles (Photo #87) were broken off at varying heights up to 4,500 feet from GZ and were burned (Photo #85) at a distance of 6,500 feet from GZ. Cable (Photo 98) was stripped from the hangers at a distance of 8,000 feet from GZ, but the poles were upright and the cable was otherwise undamaged. Figure 13 indicates the extent of damage to the overhead system and shows the distances to GZ. Table 24 lists damage to the overhead transmission system.

TABLE 24.—*Damage to overhead system*

No. of pairs per cable	Central district (feet)	Western district (feet)
200	374	-----
100	47,850	23,790
50	29,650	17,180
25	12,600	6,700
15 and under	2,262	1,320
Wood poles	4,551	2,293

No concrete poles were damaged (Photo *23). Approximately 80 percent of the overhead system of both the Central and Western District was damaged. The salvage value of the damaged equipment and materials for the overhead systems was estimated at 10 percent.

d. Upon examination of the subsurface transmission system by officials of the Bureau of Telephones subsequent to the attack, no damage to manholes or ducts was found. Examination of manholes by members of the survey revealed no evidence of cracks, breaks, or other damage. Although no actual damage was done to the subsurface system in itself, the damage to bridges (Photos 99 through 104) serving as overcrossings and exit points on conversion to the overhead system put out of service approximately 80 percent of the subsurface system. Table 25 indicates the damage to bridges as estimated by the Bridge Damage Section.

PHOTO 89–XIII. Bureau of Telephones' Central District Exchange Building showing damaged equipment, 2,000 feet from CZ.

PHOTO 90–XIII. Equipment damage in the Central District Exchange Building.

PHOTO 91–XIII. Bureau of Telephones' Western District Exchange Building, 3,300 feet from GZ.

PHOTO 92–XIII. Equipment damage in the Western District Telephone Building.

PHOTO 93–XIII. Telephone-cable transition from subsurface to overhead system damaged by blast and fire, 1,200 feet from GZ.

PHOTO 94–XIII. Damaged wood pole and cable, 2,500 feet from GZ.

PHOTO 95–XIII. Stripped cable 4,500 feet from GZ.

PHOTO 96–XIII. Steel-lattice poles, 6,000 feet from GZ. Poles were downed by blast across road, but were removed to make way for traffic.

PHOTO 97–XIII. Damaged cable, 7,500 feet from GZ.

PHOTO 98–XIII. Cable downed, 8,000 feet from GZ.

TABLE 25.—*Damage to overcrossings*

Bridge	Grid	Length (feet)	Distance from GZ (feet)	Type	Cause of damage	Extent of damage	Number of pairs per cable
6	4I	266	6, 100	Timber	Blast and fire	Complete destruction	100
13A	5I	307	4, 700	do	do	do	1, 800
21	5H	295	1, 400	do	Blast	do	1, 000
24	4G–H	398	1, 000	Plate girder	do	Slight damage	800
29	5G	263	1, 200	Pin-connecting truss	do	Complete destruction	2, 000

Figure 13 shows the location of the damaged bridges. Although Bridge 24 was not down (Photos 103 and 104), the severe blast effects parted the transmission cables. There was no damage to subriver crossings. Thus, the several types of damage put out of service the cables in each district as given in Table 26.

TABLE 26.—*Damage to subsurface system*

Number of pairs per cable	Central district (feet)	Western district (feet)
1,200	3, 880	2, 540
800	6, 350	1, 470
600	6, 470	3, 250
400	5, 300	1, 200
200	1, 320	200
100	860	32
50	1, 700	6, 666

Repairs and reconstruction began almost immediately and by 15 August 1945, 35 pairs of subsurface transmission cables were back in service. These were used entirely by the prefectural government and Japanese military units. Since the equipment in the Central District Exchange Building was totally damaged, all telephone traffic was routed through the Western District Exchange. With the exception of the breaks at bridge crossings, connections were remade in subsurface circuits. By 30 August 1945, 50 pairs were available for long-distance use with the following cities: Tokyo, Osaka, Okayama, Shimonoseki, Fukasho, Iwakuni-Beppu, Matsuama, Takamatsu, Zentsuji, and Matsue Hamada. Ten lines devoted to outlying vicinities of Hiroshima. During the floods of September 1945 and 5 October 1945, additional serious damage was added to that suffered as a result of the atomic-bomb attack. More bridges serving as overcrossings were damaged, as given in the following table:

TABLE 27.—*Damage to overcrossings by flood*

Bridge	Grid	Length (feet)	Type	Number of pairs per cable	Extent of damage
31	6H	358	Concrete	100	Severe damage.
33	6F	410	do	100	Do.
37	5G	180	Plate girder	2, 000	Do.

The remaining bridges were undamaged. Additional repairs had to be made and circuits rerouted. As explained in the Sanitary and Storm Sewer Section of this report, water tables that were normally 8 to 12 feet below ground elevation rose to within 3 feet of ground elevation (Photo 105). Since manholes were neither water-proofed nor drained, water seeped through the concrete walls and saturated the conduits. This caused more delay in the repair of the remaining subsurface system. Cables, being lead-sheathed and well protected at manhole intersections, were not water damaged. The telegraphic system under the Bureau of Telegraphs was totally damaged, and the system was merged with the Bureau of Telephones. One telegraph line communicating with Tokyo and Osaka was operating by the middle of September 1945.

e. The cost of damage, as estimated by the Bureau of Telephone officials on 15 November 1945, was approximately 10,000,000 yen, or $2,500,000, at the 4-yen-to-a-dollar rate of exchange.

f. Of the 900 persons employed by the Bureau of Telephones, there were 350 persons killed, injured, or missing in the Central District Exchange Building and maintained areas, but none were killed in the Western District Exchange Building.

g. Information regarding telephones, telephone equipment, telephone transmission system, and personnel was acquired from the chief engineer of the Bureau of Telephones in Hiroshima.

PHOTO 99–XIII. Damage to cable at Bridge 13A, 4,700 feet from GZ.

PHOTO 100–XIII. Damage to 2,000-pair cable at Bridge 29, 1,200 feet from GZ.

PHOTO 101–XIII. Flood damage to Bridge 31 carrying 100-pair cable, 4,600 feet from GZ.

PHOTO 102–XIII. Flood damage to Bridge 37 carrying 1,000-pair cable, 3,200 feet from GZ.

PHOTO 103–XIII. Damage to telephone conduit cable at Bridge 24, 1,000 feet from GZ.

PHOTO 104–XIII. Broken cable conduit at Bridge 24.

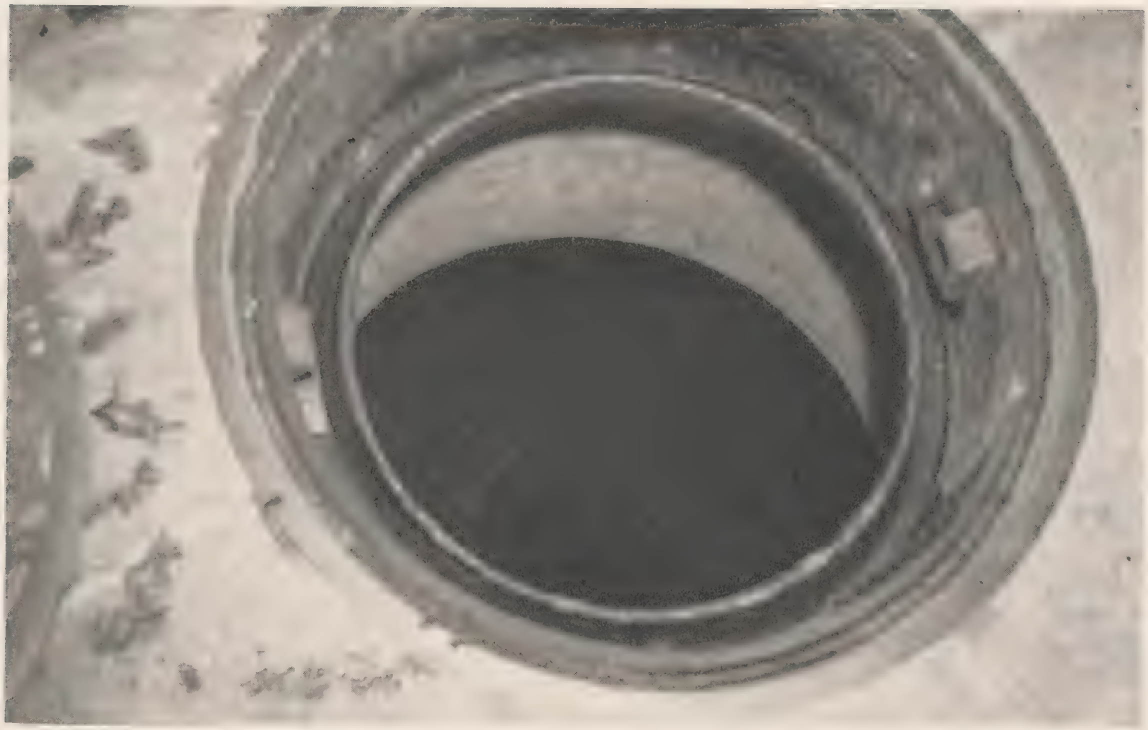


PHOTO 105–XIII. Water-filled, telephone manhole.

PHOTO 106 XIII. Debris-damaged telephone manhole cover 100 feet from GZ. Secondary cover undamaged.

4. Recommendations and Conclusions

a. At the time of the attack the telephone communications system, although well designed and maintained, was particularly vulnerable to an air-detonated atomic bomb because of the method of transmission. The reasons for the disruption of 80 percent of both the overhead and the subsurface transmission systems were as follows:

(1) The overhead system was carried on wood poles which were vulnerable to blast and fire.

(2) Damage by fire and blast occurred at points of conversion from subsurface to overhead system.

(3) The bridges used as overcrossings for cables were damaged by blast and fire.

b. Had the subsurface system been divorced from overcrossings and had subriver crossings been used with well-protected exits to overheads, this part of the entire system would have been practically free of damage. Thus, the best protection against this type of attack for telephonic communications would have been an entire subsurface system for the city proper. The subsurface system would have minimized the necessity of repairs. As shown by the existing subsurface system at Hiroshima, no damage occurred to the conduits or manholes 4 feet below ground level.

c. Exchange buildings would have to be numerous, well dispersed, and completely interconnected as stand-by units to insure service in the event of damage to the primary equipment.

E. WATER SUPPLY SYSTEM

1. Summary

a. Capacity. The city of Hiroshima maintained a water supply system capable of producing 20,000,000 gallons of filtered water per day, or an average of 50 gallons per day per person. This system served approximately 90,000 buildings and dwellings including factories and other plants that required filtered water. In addition to the potable water, wells were dug or drilled as supplementary sources for industrial and other uses.

b. Location. The purification plant was approximately 2 miles in a northerly direction from the center of the city and the pumping station was one mile beyond the purification plant. Both were located on the Ota River (Fig. 16).

c. Equipment. Table 28 shows the buildings utilized by the water supply system. Building 1 had four river-intake pumps; Building 3 housed the standby units consisting of three Diesel-motor pumps and one generator; Building 4 contained three booster pumps; two recording meters were in Building 5; in Building 6 were four reservoir pumps; and the pumping station had four river-intake pumps.

d. Filter Beds. There were seven sand filter beds of 21,120 square feet each, with a 23-foot filtration rate per day through 3 feet of sand.

e. Reservoir. A reinforced-concrete, earth-covered reservoir of 4,500,000 gallons capacity was located 165 feet above the purification plant.

f. Piping. All subsurface piping was standard 250-pounds-per-square-inch, cast-iron, bell-and-spigot pipe. Equipment connections had screw ends with flange and bolt connections. Table 29 shows the lengths of cast-iron mains used in Hiroshima. Branches for dwellings varied from ½ to 1¼ inches and, for buildings, 2 to 4 inches. All mains were buried 4 feet below ground elevation.

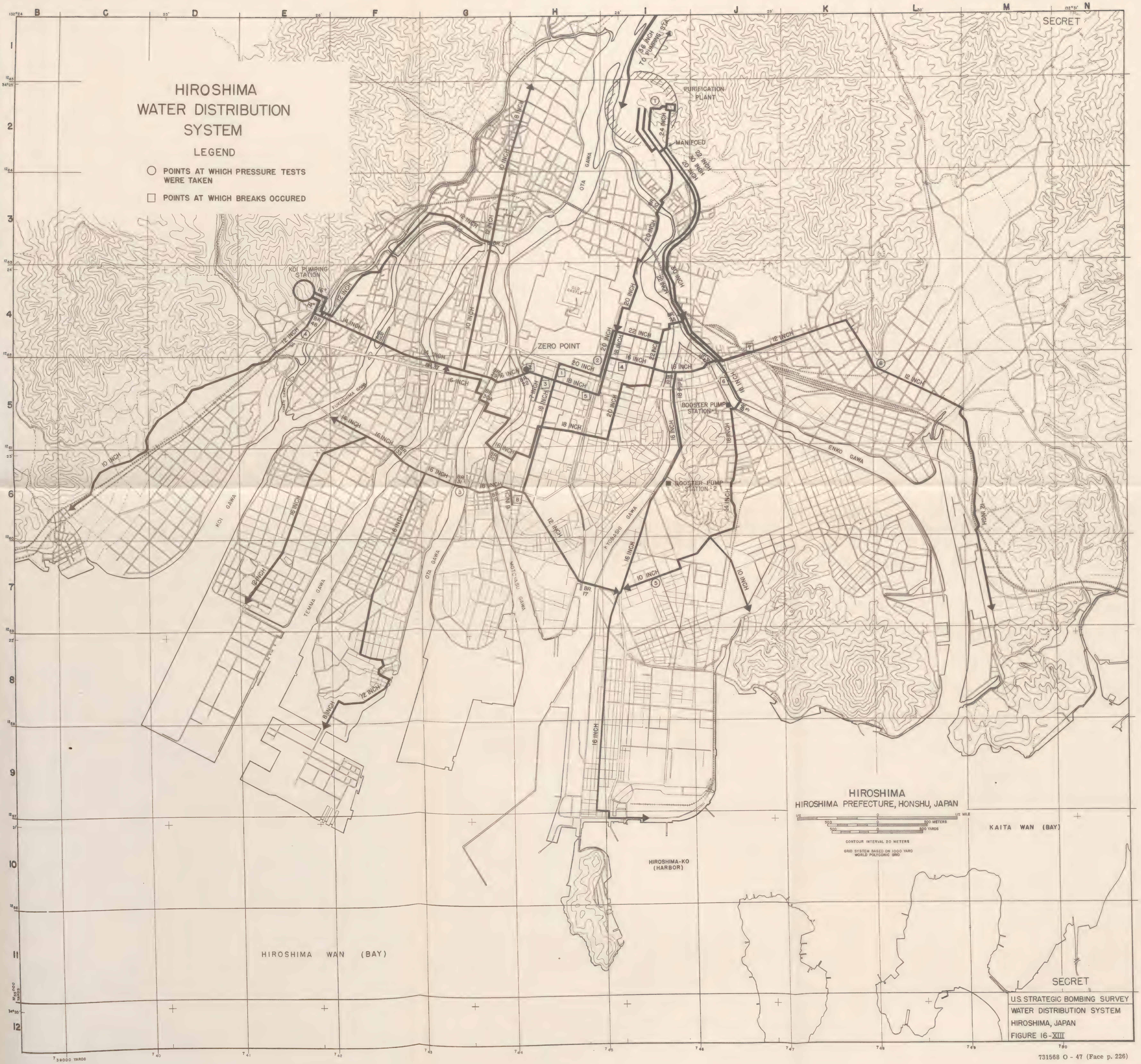
g. Valves and Hydrants. There were approximately 132 cast-iron gate valves rated at 250-pounds-per-square-inch pressure. Hydrants were of two types, standard and flush, and were spaced 600 feet apart in congested areas.

h. Booster Pumps. There were three booster pumping stations, including the one at Koi. At the Koi station there was also a reinforced-concrete water tower of 234,000 gallons capacity.

i. Overcrossings. Because of the delta system on which the city of Hiroshima was built, 17 river crossings were required. Of these, 14 were on bridges constructed and maintained by the city highway department and the prefectural government; the remaining three were aqueducts, constructed and maintained by the water department of Hiroshima. Table 32 gives the overcrossings and the sizes of mains carried.

j. Camouflage. Attempts at camouflage were made by the Japanese to conceal the purification plant and the Koi booster station.

k. Damage to Equipment and Buildings. Damage by blast to the pumping station at 14,000 feet, and the purification plant at 9,200 feet from GZ was slight. No fires occurred in these areas. One mootor in building 4 was burned out because of falling debris, and the metering equipment in building 5 suffered heavy damage. Building damage is found in Table 28. All buildings in Table 28 are classified similarly to the buildings of the building damage section. Any conclusions drawn for the mean areas of effectiveness for buildings and equipment in that section will also apply to the buildings and equipment in this section.


SECRET
HIROSHIMA
WATER DISTRIBUTION
SYSTEM
LEGEND
POINTS AT WHICH PRESSURE TESTS WERE TAKEN
POINTS AT WHICH BREAKS OCCURED
PURIFICATION PLANT
MANIFOLD
56 INCH TO PUMPING STA.
24 INCH
22 INCH
30 INCH
20 INCH
KOI PUMPING STATION
OLD CASTLE
ZERO POINT
BOOSTER PUMP STATION 1
BOOSTER PUMP STATION 2
OTA GAWA
KOI GAWA
TEMMA GAWA
FUKUSHIMA GAWA
MOTOYASU GAWA
KYOBASHI GAWA
ENKO GAWA
12 INCH
10 INCH
14 INCH
16 INCH
18 INCH
8 INCH
HIROSHIMA
HIROSHIMA PREFECTURE, HONSHU, JAPAN
CONTOUR INTERVAL 20 METERS
GRID SYSTEM BASED ON 1000 YARD WORLD POLYCONIC GRID
KAITA WAN (BAY)
HIROSHIMA-KO (HARBOR)
HIROSHIMA WAN (BAY)
SECRET
U.S. STRATEGIC BOMBING SURVEY
WATER DISTRIBUTION SYSTEM
HIROSHIMA, JAPAN
FIGURE 16-XIII

l. Damage to Piping. Hiroshima water department officials attributed eight leaks in the mains to the attack. Upon inspection, it was the opinion of the team that one leak was developed by the action of Bridge 22 which was directly affected by the blast, and that the remaining leaks resulted from falling debris and other causes. There were no crushed mains. Approximately 70,000 branches were fractured or dislocated when buildings were damaged by blast and fire.

m. Valves and Hydrants. One cast-iron valve, 4 inches in diameter, and a few standard hydrants were damaged by falling debris. No flush-type hydrants were damaged.

n. Booster Pumps. The booster pumping station equipment was damaged only slightly, but the buildings of Stations 1 and 2 were structurally damaged by the blast.

o. Overcrossings. Bridge 29 which carried a 16-inch main was put out of service; this damage, however, had no effect since a 16-inch main across Bridge 30A served the same district. Bridge 43, carrying a 14-inch main, suffered damage by blast and fire which greatly decreased the water volume in the area which it served. Floods of 17 September and 5 October 1945 damaged other structures. Table 32 is a summary of bridge damage. All bridge data are classified in the Bridge Damage Section, and any conclusions drawn for the mean areas of effectiveness for bridges and their attendant utilities are applicable to this section.

p. Cost of Damages. The cost of damages as estimated on 15 November 1945 was 3,000,000 yen, or $750,000 at the rate of 4-yen-to-a-dollar.

2. Description of the System

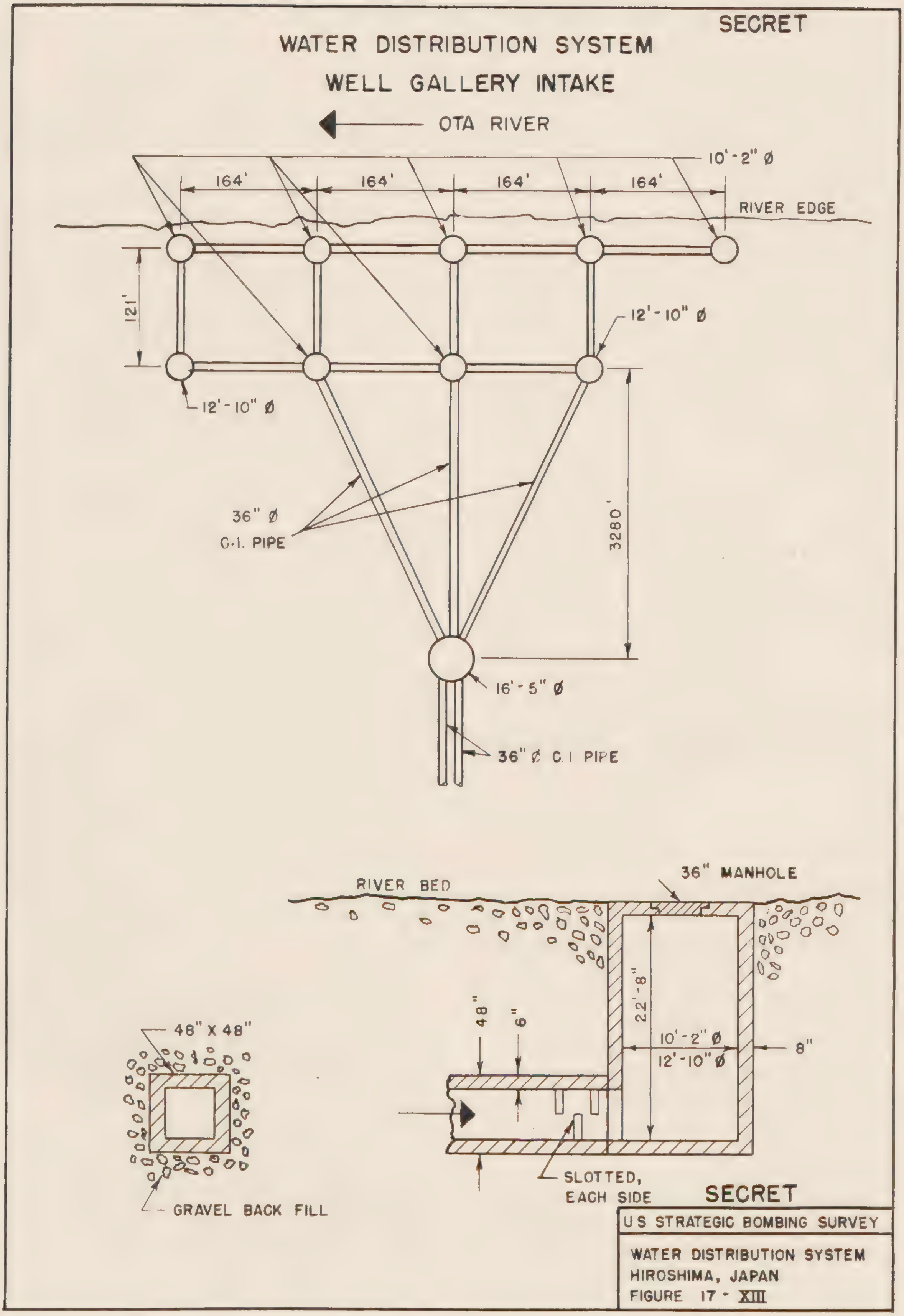
a. In order to give a better description of the water distribution system, Figures 16 and 18 are included to show the locations of buildings and piping of the pumping station and the purification plant, as well as the distribution system within Hiroshima, including booster pumps.

b. The purification plant was approximately 2 miles north of the center of the city, and the pumping station was located 1 mile beyond the purification plant, both on the Ota River. Water was taken from the Ota River and, after being processed in the purification plant, was piped to Hiroshima. The average daily water-consumption rate was 20,000,000 gallons or 50 gallons per day per person. Approximately 90,000 buildings and dwellings were serviced, including factories and production plants which required pure water for operations. The 90,000 buildings and dwellings were divided into 12 water districts and 4 communities, namely Kusatsu, Misasa, Niho, and Mukainada. The population of each district or community varied in size and density of population, ranging from 6,700 people in Mukainada to 71,000 in District 12. In addition to the water-distribution system, 85 percent of the dwellings had wells from which water for other uses was drawn. These wells were either dug or drilled to obtain water at the normal water table which was from 12 to 16 feet below ground level. Approximately 20 percent of the wells were dug and 80 percent were drilled. Thus, with a combination of the water-distribution system and the well system, there was more water available than the daily average of 50 gallons per day per person furnished by the public system.

c. The pumping station shown on Figure 16 was approximately 1,200 feet from the Ota River. A series of interconnected wells, as shown on Figure 17, collected the subsurface water from the Ota River and four electrically-operated, centrifugal pumps transferred it from the river intake to the filtration plant. Each pump had a capacity of 5,220 gallons per minute against a head of 75 feet, and was powered by an electric motor of 165 horsepower at 3,000 volts. The pumping units were designed and manufactured by the Inoguchi Shibaura Motor Co. of Tokyo. The pumping station building was of heavy, reinforced-concrete design with a 3-ton traveling crane; the building classification is indicated on Table 28. The station was electrically operated and all pumping-unit switches and telltale lights were operated from a single cabinet panel. A single 36-inch, cast-iron, bell-and-spigot main carried water to the purification plant.

d. Figure 18 shows the general arrangement of the purification plant, including buildings, basins, and reservoirs. When raw water was taken at this plant from the Ota River an intake gate or intake tower provided an ingress to the system, as shown on Figures 19 and 20.

e. Two 18-inch, cast-iron pipes, or two alternate, 24-inch cast-iron pipes (Fig. 18) carried the water to the intake pumps and straining basin as detailed on Figures 21 and 22. Raw water from the pumping station also flowed through this system. It was necessary to have three intake systems because of the heavy flow of alluvial material in the


SECRET
WATER DISTRIBUTION SYSTEM
WELL GALLERY INTAKE
OTA RIVER
10'-2" Ø
164'
164'
164'
164'
RIVER EDGE
121'
12'-10" Ø
12'-10" Ø
36" Ø
C.I. PIPE
3280'
16'-5" Ø
36" Ø C.I PIPE
RIVER BED
36" MANHOLE
22'-8"
48"
6"
10'-2" Ø
12'-10" Ø
8"
48" X 48"
SLOTTED,
EACH SIDE
GRAVEL BACK FILL
SECRET
U S STRATEGIC BOMBING SURVEY
WATER DISTRIBUTION SYSTEM
HIROSHIMA, JAPAN
FIGURE 17 - XIII


GENERAL ARRANGEMENT
OF PURIFICATION PLANT.
GENERAL PLAN.
1 SHAKU = 0.994 FT.
FEET = FT.
SHAKU = S U.
S.B. 1
S.B. 2
S.B. 3
F. B. 1
F. B. 2
F. B. 3
F. B. 4
F. B. 5
F. B. 6
F. B. 7
RELATIVE HEIGTS OF BASINS.
USSBS Report 69
HIROSHIMA
FIG 18-XIII

Table 28–XIII.—*Hiroshima water distribution system—building data*

[Areas in thousands of square feet]

Building	Grid	Usage	Type	Plan area	Stories	Building HE–V	Building Fire–V	Distance AZ (feet)	Total floor area	Building damage (floor area)						Equipment damage	
										Structural damage			Superficial damage		Minor damage	Per cent	Cause
										Blast	Fire	Mixed	Blast	Fire			
1		Pump house	D	1.4	1	V4	R	9,200	1.4						Slight		None.
2		Storehouse	D	1.4	1	V4	C	9,200	1.4						do		Do.
3		Pump plant	A2.3	15.3	1	V4	C	9,200	15.3				1.1		Moderate		Do.
4		Pump house	D	.6	1	V4	C	9,200	.6				.2		do	50	Debris.
5		Meter station	D	.3	1	V4	R	9,200	.3						do	20	Blast.
6		Pump house	D	2.1	1	V4	C	9,200	2.1				.5		do		None.
7		Chlorine plant	D	.2	1	V4	R	9,200	.2						Slight		Do.
8		Office	D	.8	1	V4	C	9,200	.8				.8		Severe		
9		Watch station	D	.4	1	V4	C	9,200	.4						Slight		
Pump station.		Pump house	D	2.6	1	V4	R	14,000	2.6						do		Do.

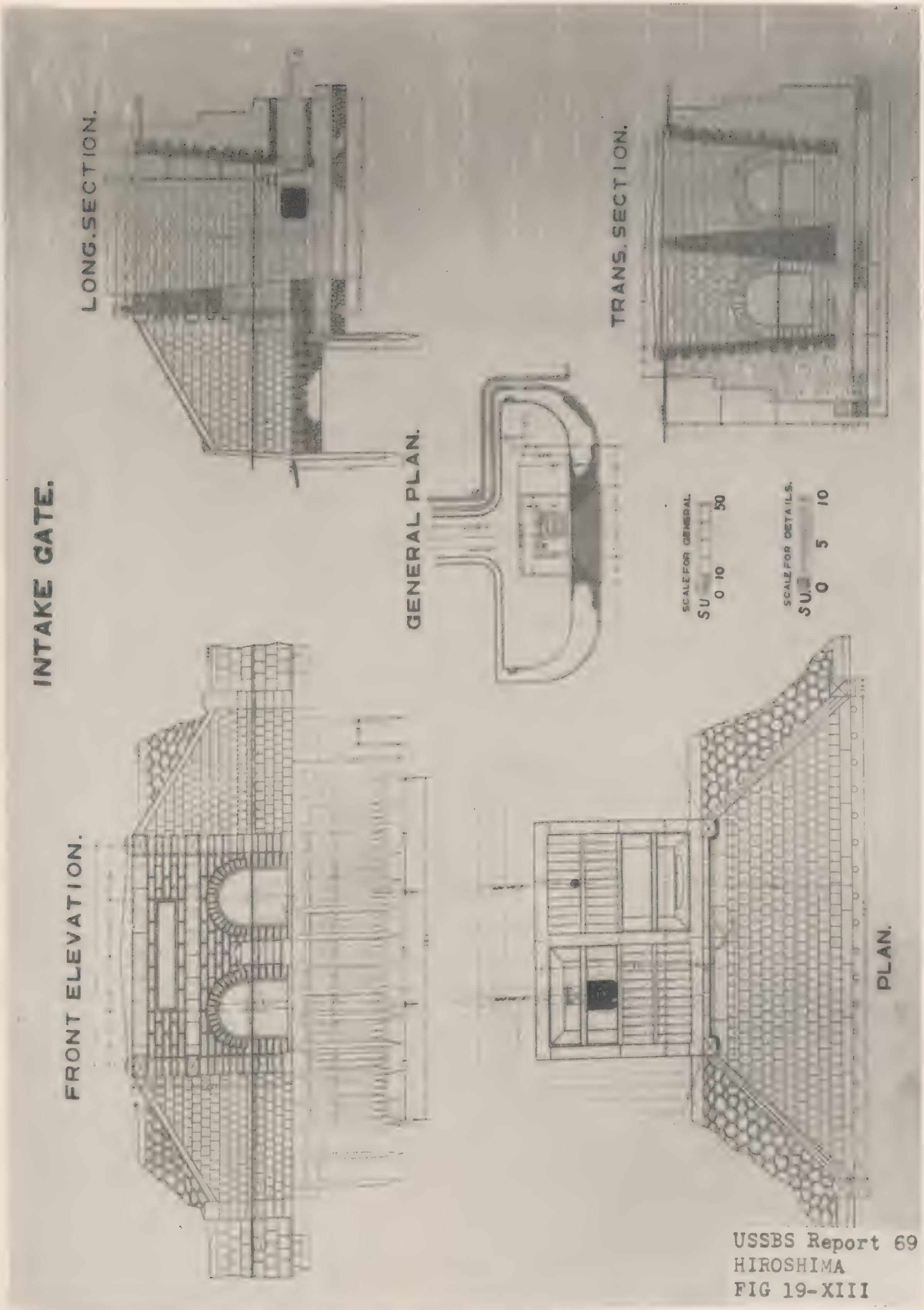
Ota River which completely filled the intakes with sand and gravel during flood stages.

f. The four intake pumps in Building 1 had a capacity of 2,600 gallons per minute against a 32-foot head. The electric motors for the pumps were rated 35 horsepower at 3,000 volts AC. Pump units were of Japanese design and manufacture. In order to insure a continuous flow of water, the Diesel-powered pumps in Building 3 (Figs. 23, 24, and 25) were used as a stand-by unit in case of break-down of the main pumps in Building 1. The three Diesel engines and pumps were of Deutz design and German manufacture, each having a capacity of 2,620 gallons per minute at 200 horsepower against a 32-foot head. In addition to the main and auxiliary pump station, a booster station at Building 4 was maintained consisting of three electrically operated pumps, each having a capacity of 3,320 gallons per minute at 210 horsepower against a 32-foot head.

g. The settling basins or reservoirs are shown on Figures 26 and 27. Until the outbreak of the war the water was chlorinated, but, due to the priorities placed on chlorine, none was available thereafter for water chlorination. The chlorine was introduced into the water prior to filtration. This was accomplished at the chlorination plant (Building 7), which is shown on Figure 28. The capacity of the chlorination plant was approximately 600 cubic feet of gas per day. All equipment in the plant was of Japanese manufacture and design. There were seven sand-filter beds, 21,120 square feet each, capable of a filtration rate of 23 feet of water through 3 feet of sand per day, or a total of approximately 80 acre-feet of water per day. Cleansing and processing of sand took place every 30 days. Figures 29 and 30 show details of the filter beds.

h. The pumping station at Building 6, which transferred filtered water to the reservoir, consited of four electrically driven pumps, each having a capacity of 5,220 gallons per minute against a head of 165 feet. The pumps were driven by 165-horsepower electric motors operated at 3,000 volts. One motor unit was of Swiss design and manufacture; the remaining three were manufactured by the Inoguchi Shibaura Motor Co., of Tokyo. Figures 31 and 32 show the details of this station. Building 5, the metering station, controlled the flow of water to the distribution systems. Two recording meters kept continuous charts of maximum and minimum flow at demand and slack periods.

i. It will be noted that all the powered equipment was electrically operated with the exception of the stand-by Diesel-powered pumps. The Suigenchi electric substation of the Chugoku Electric Co. (a subsidiary of the Nippon Electric Co.) provided all the power, transforming 22 kilovolts down to 3,000 volts. This power substation was located at the purification plant. In addition to the Suigenchi substation, an auxiliary source of electric power was maintained in case of failure of the Chugoku Electric system. The auxiliary unit, located in Building 3 was a Diesel-powered generator of the German Deutz type, generating 260 kilovolt-amperes at 3,000 volts. The Diesel engine developed 350 horsepower. Table 28 summarizes the buildings at the pumping station and purification plant (Fig. 23) and shows the classification.



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HIROSHIMA
FIG 19-XIII

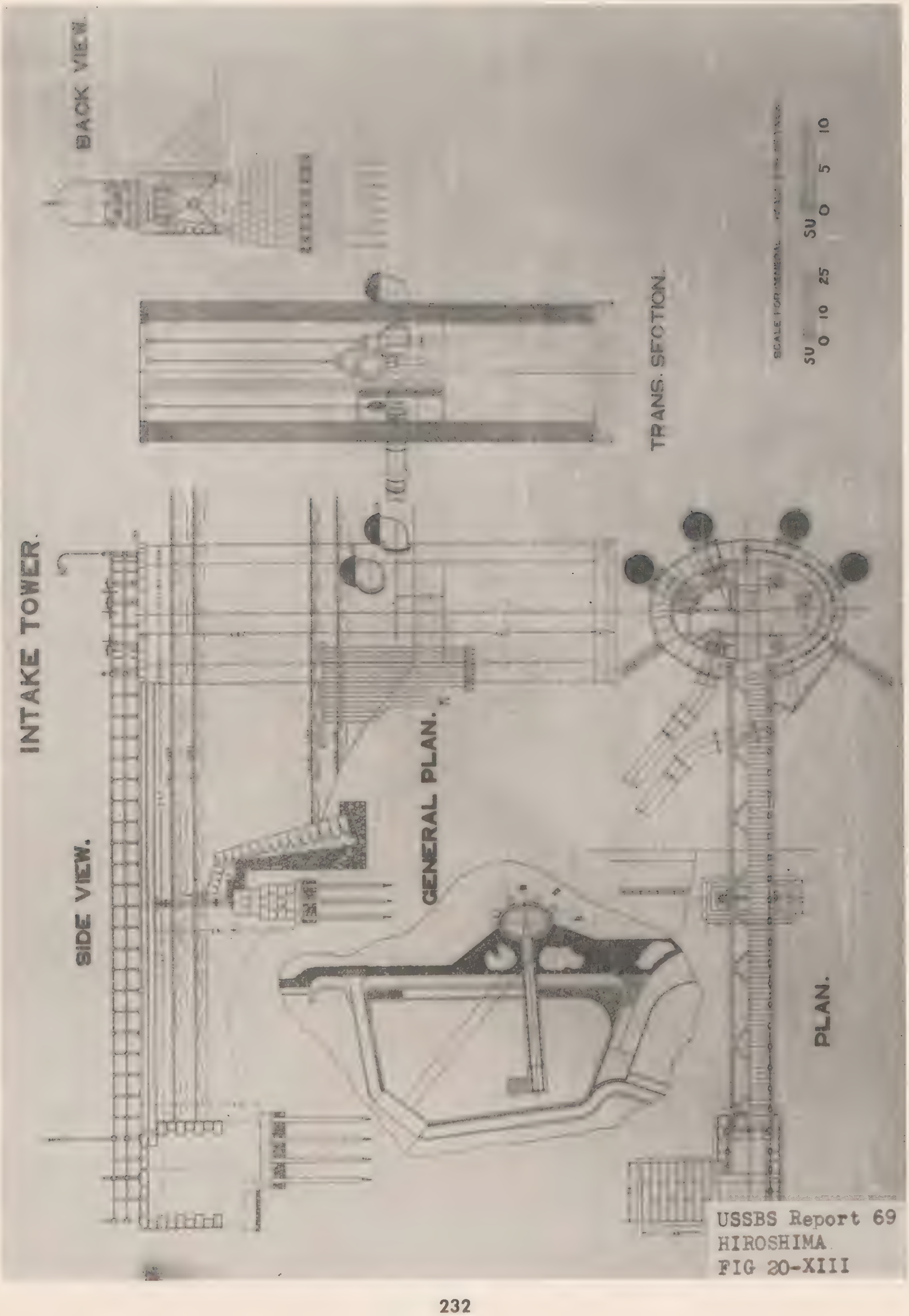

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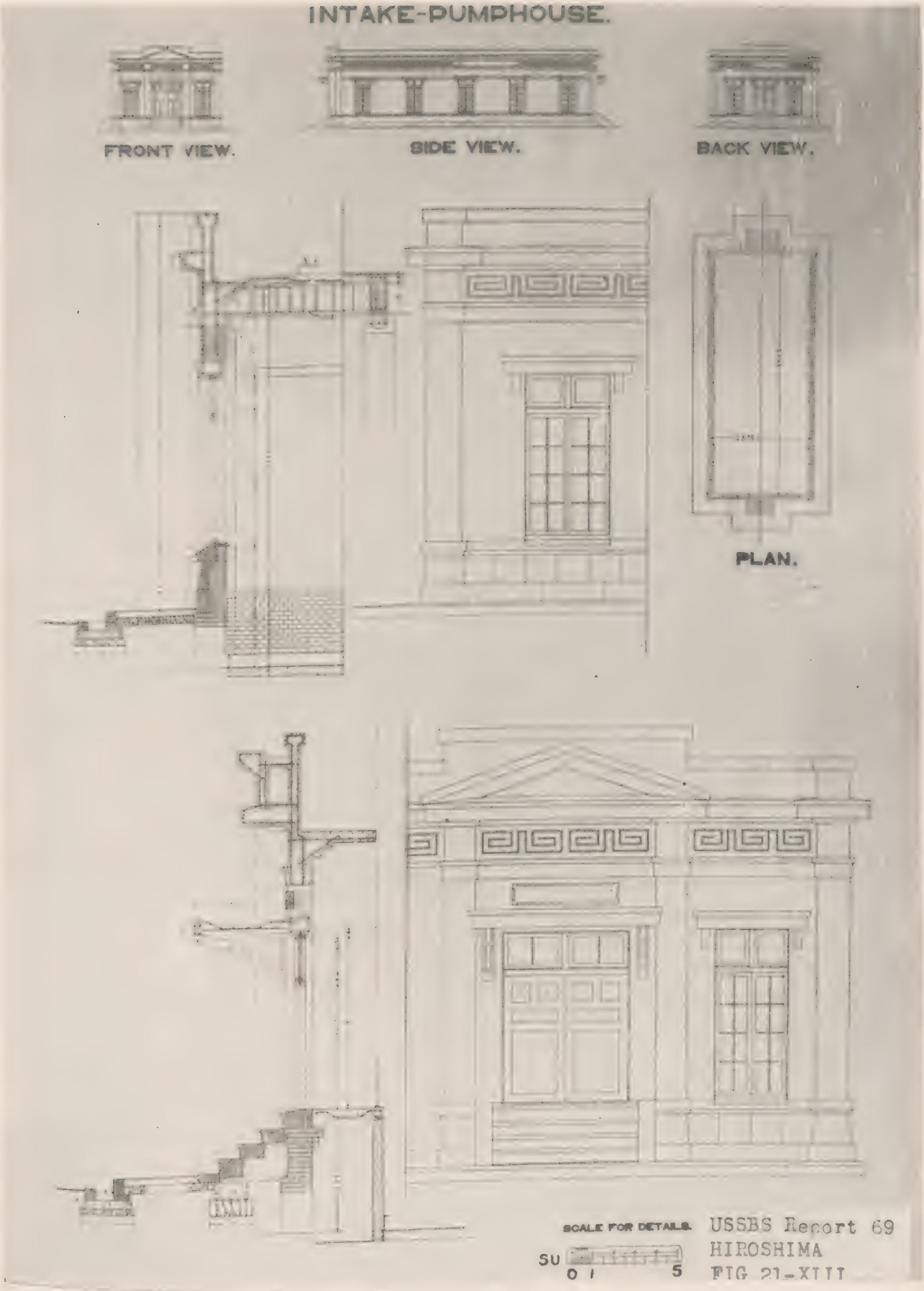
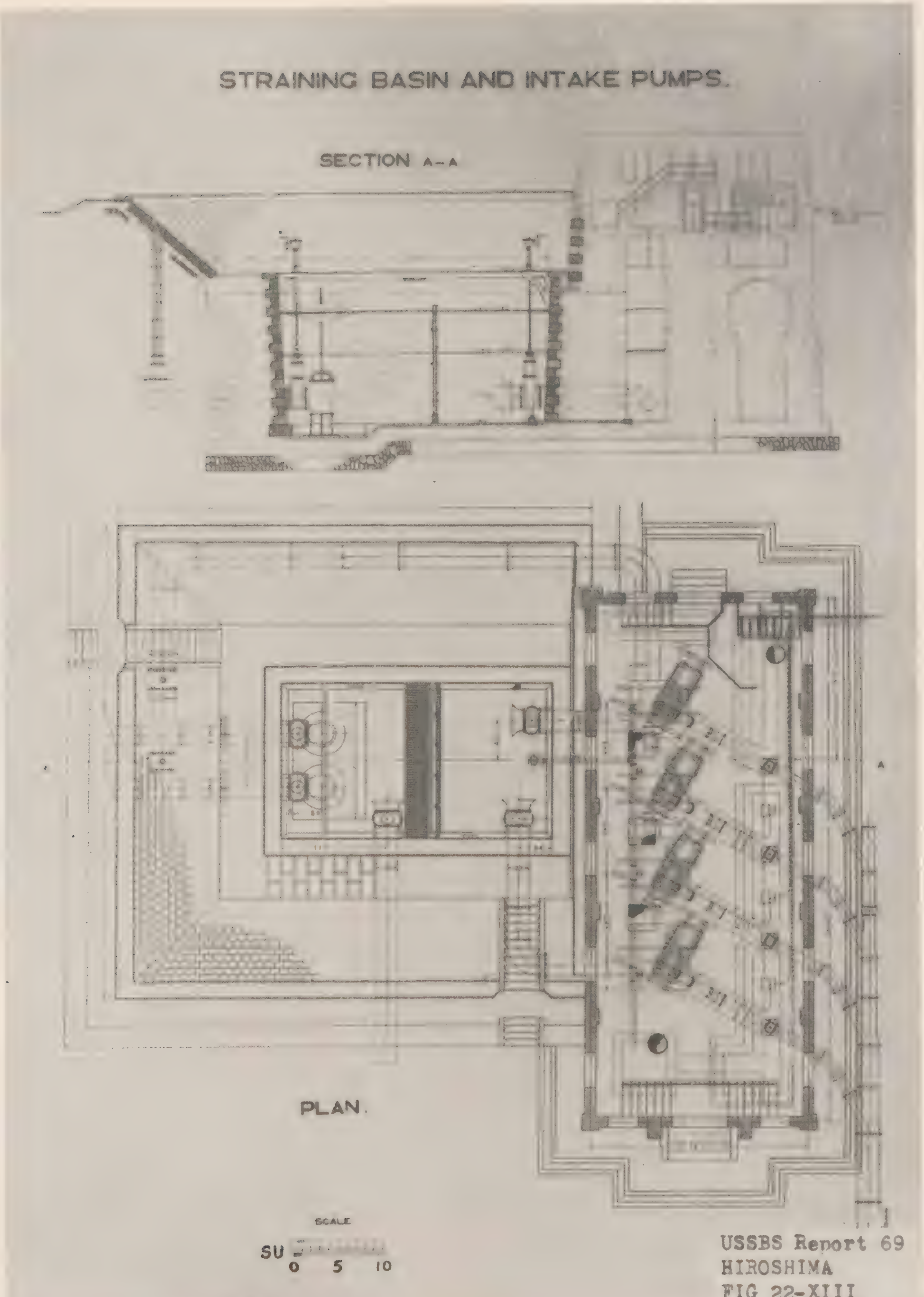
FIG 20-XIII


INTAKE-PUMPHOUSE.
FRONT VIEW.
SIDE VIEW.
BACK VIEW.
PLAN.
SCALE FOR DETAILS.
SU
0 1 5
USSBS Report 69
HIROSHIMA
FIG 21-XIII


STRAINING BASIN AND INTAKE PUMPS.
SECTION A-A
PLAN.
SCALE
SU
0 5 10
USSBS Report 69
HIROSHIMA
FIG 22-XIII

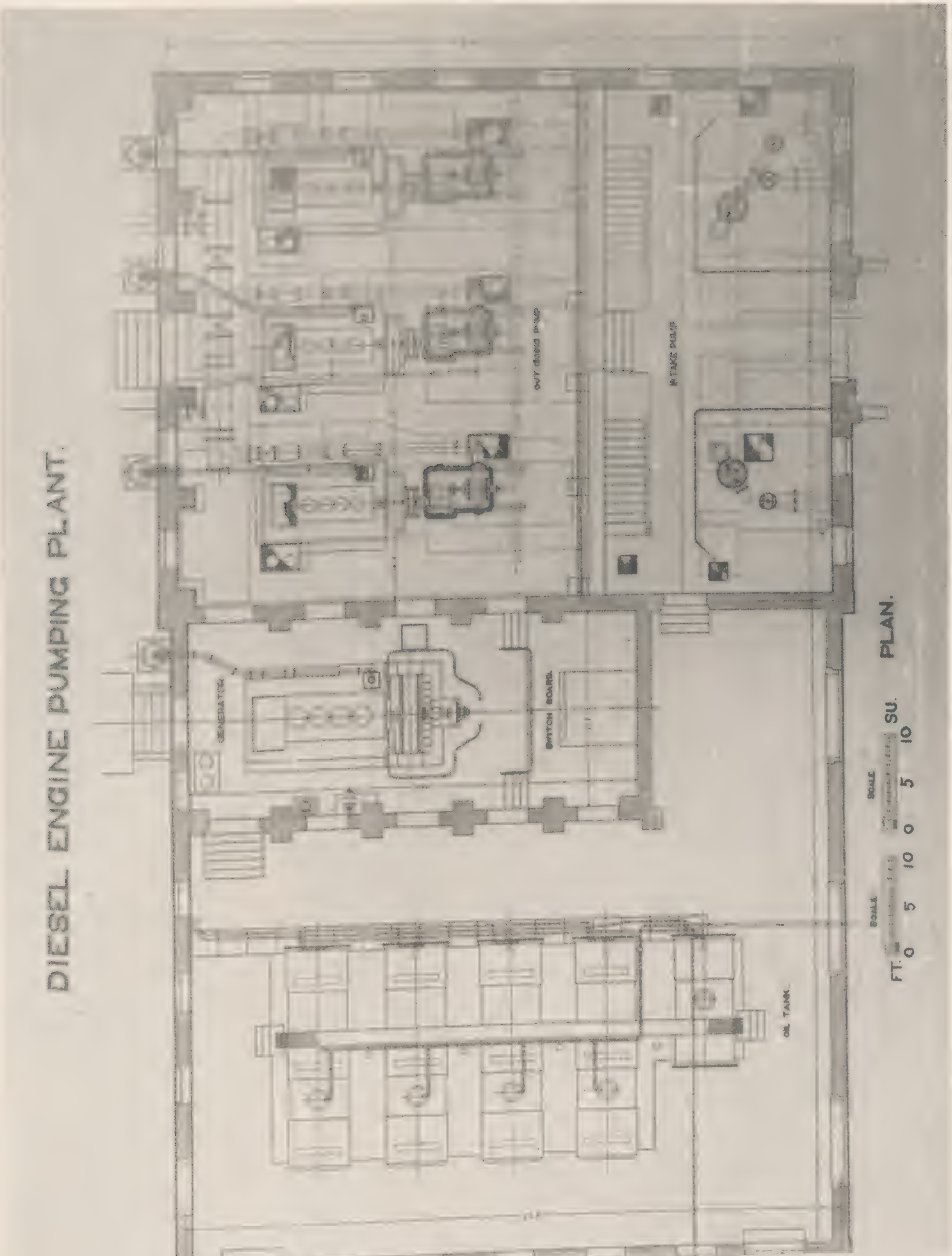


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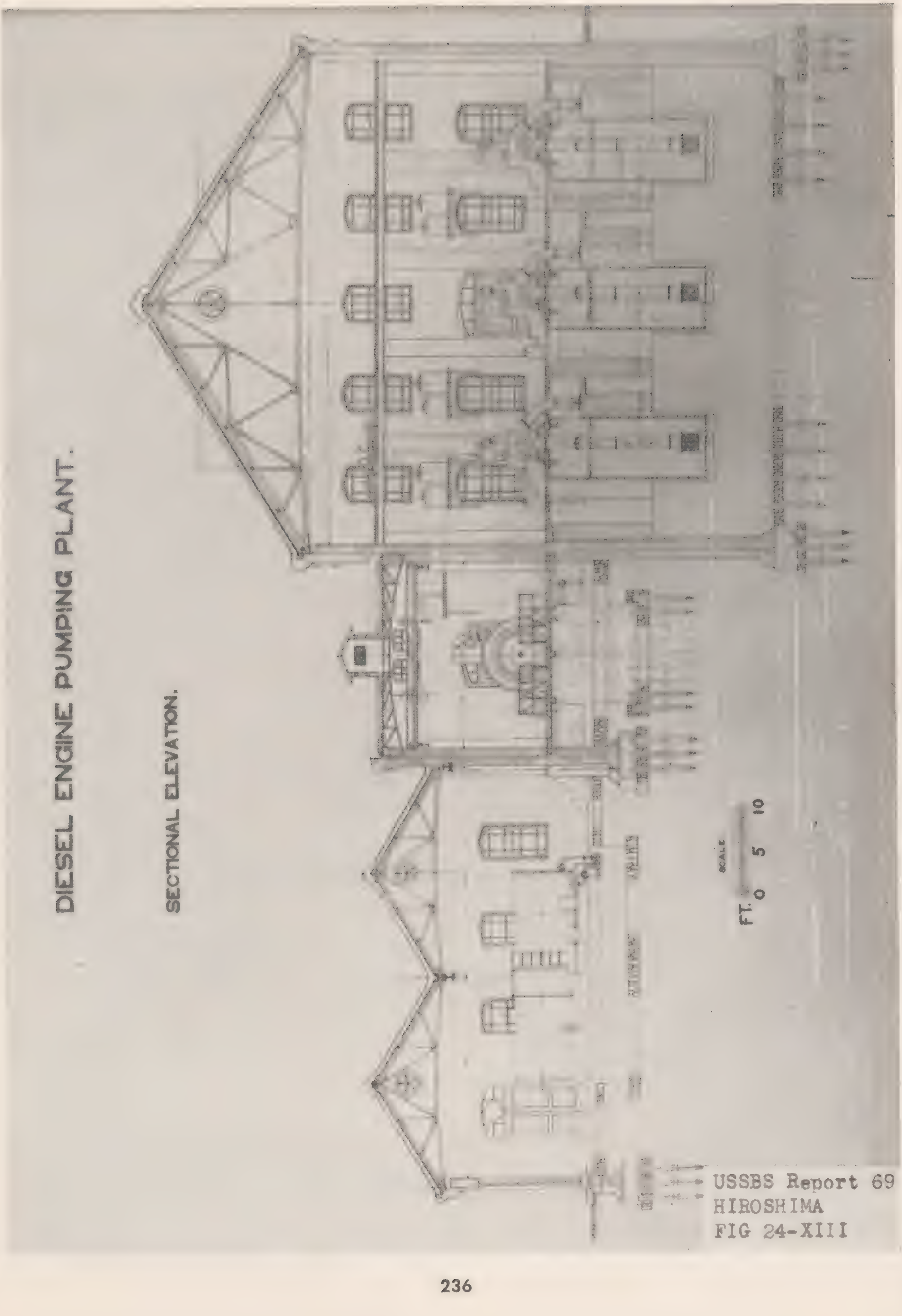
FIG 23-XIII



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HIROSHIMA
FIG 24-XIII

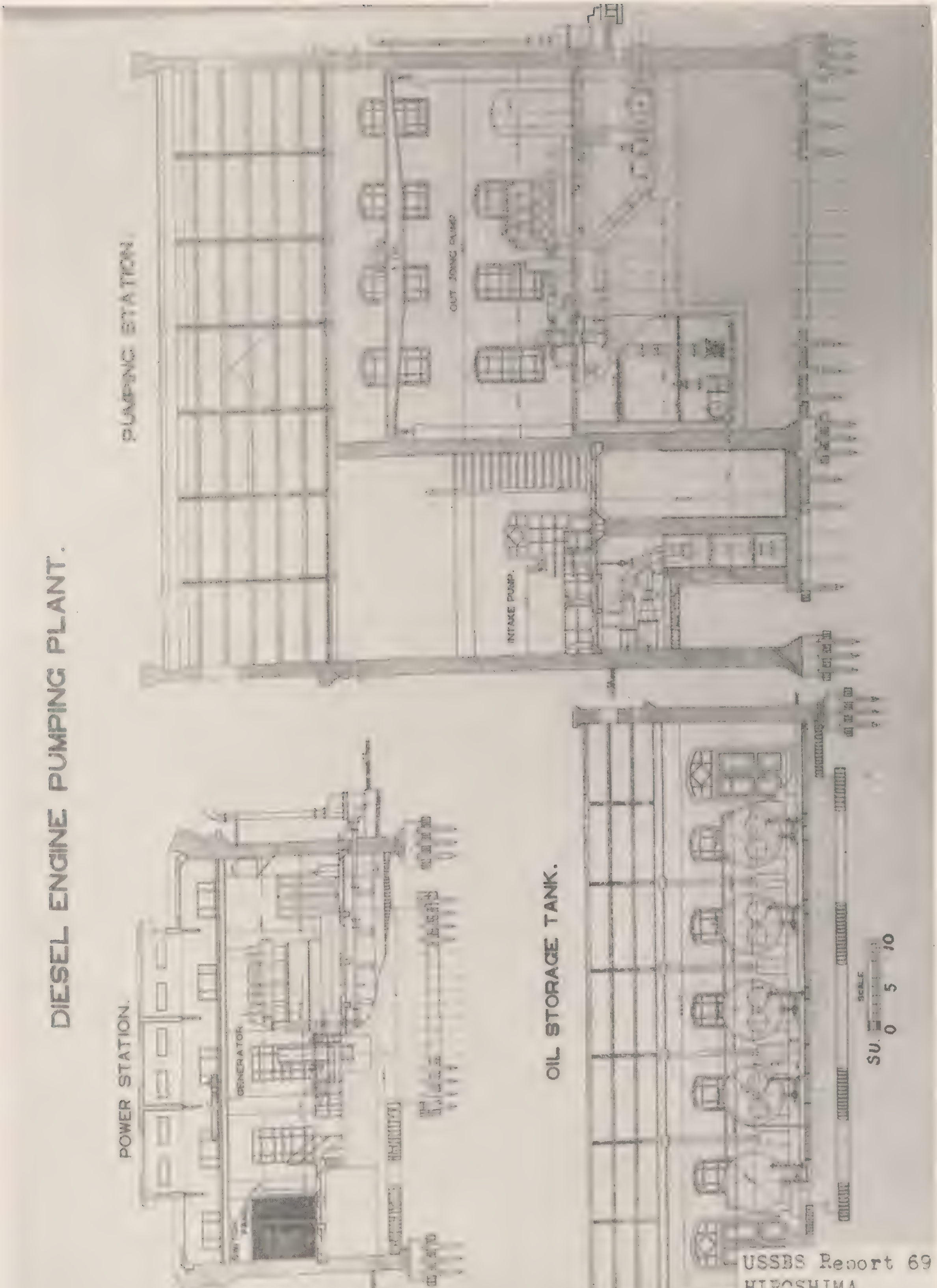

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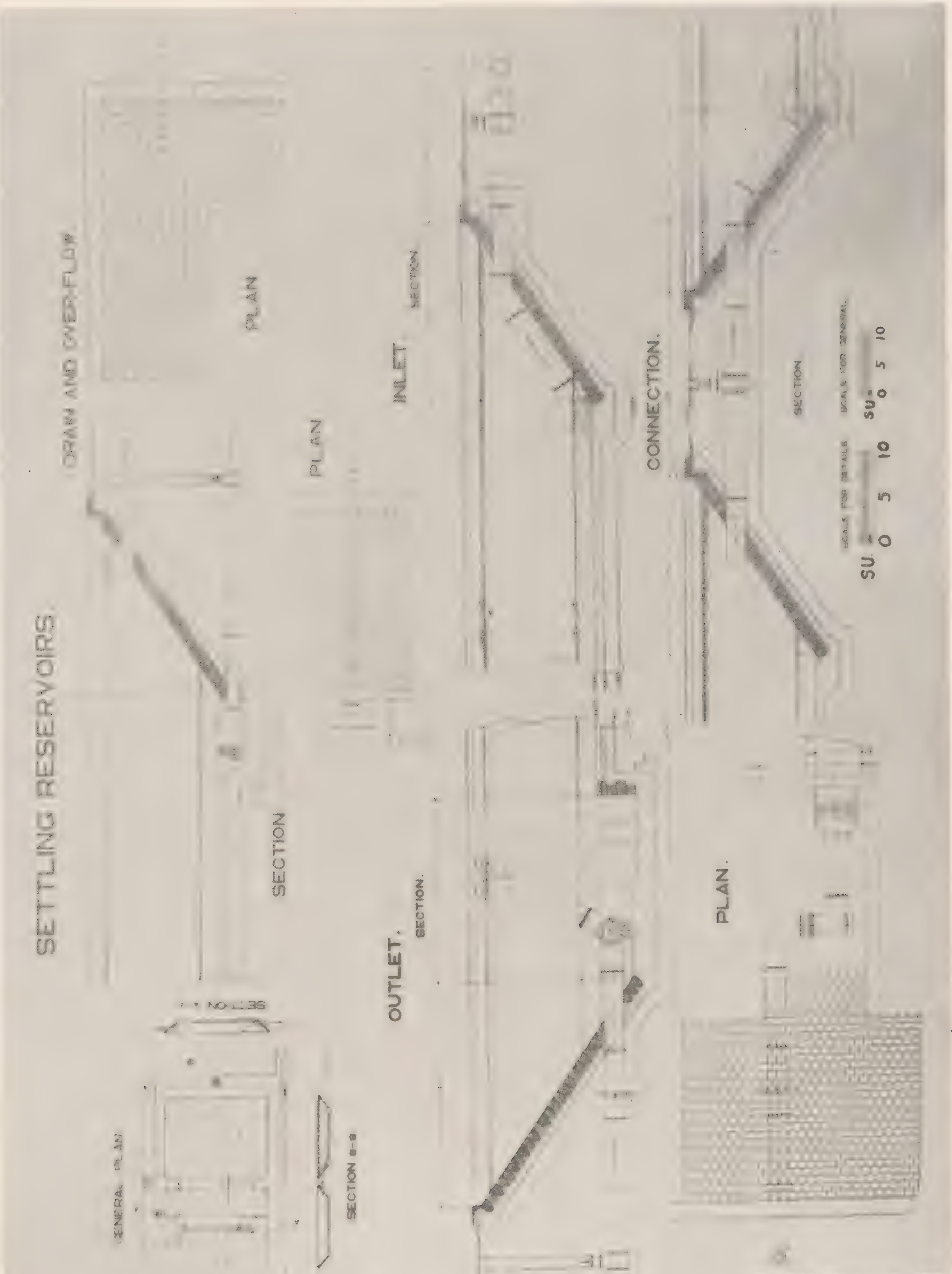
FIG 25-XIII



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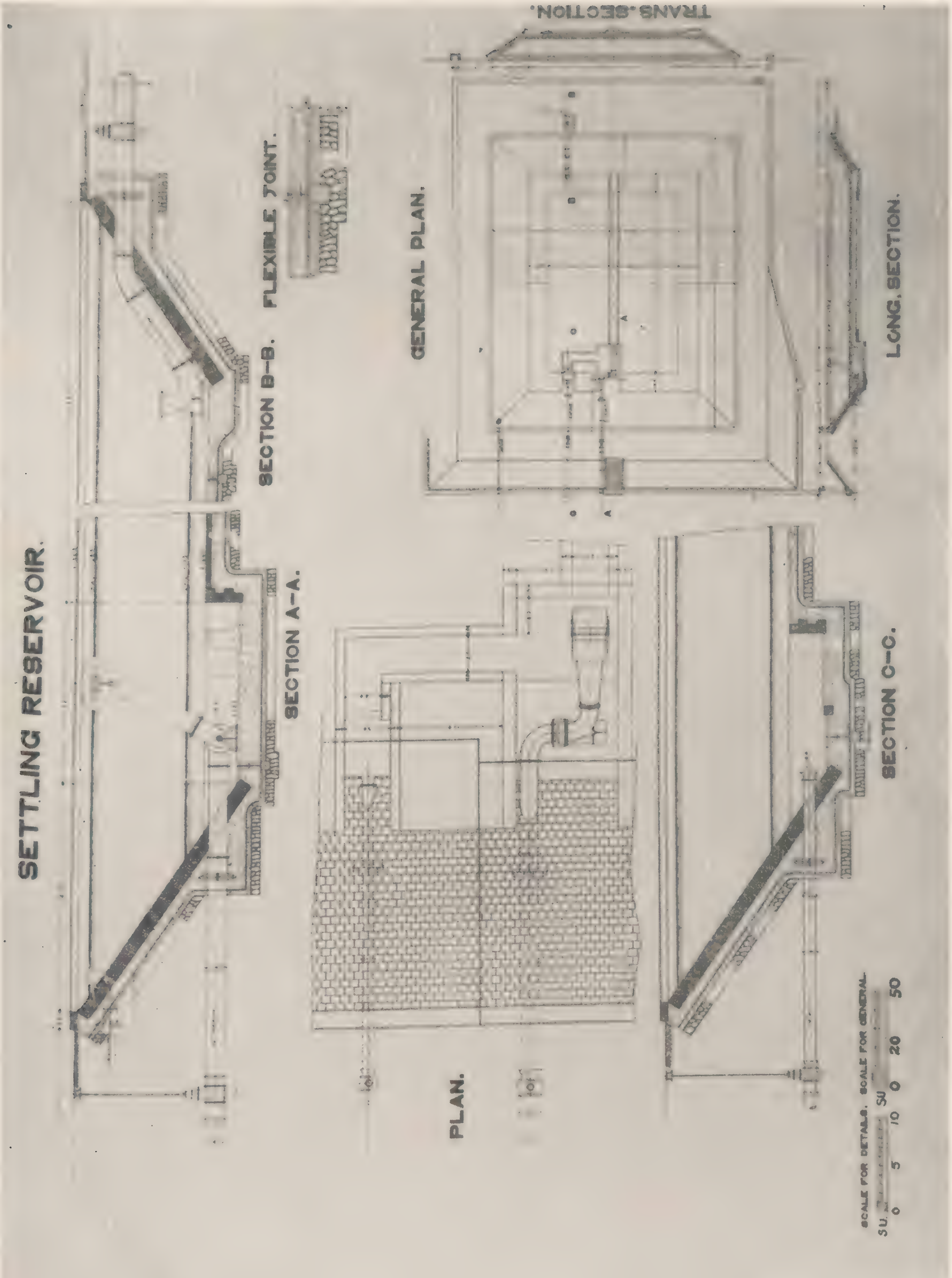
HIROSHIMA
FIG 26-XIII



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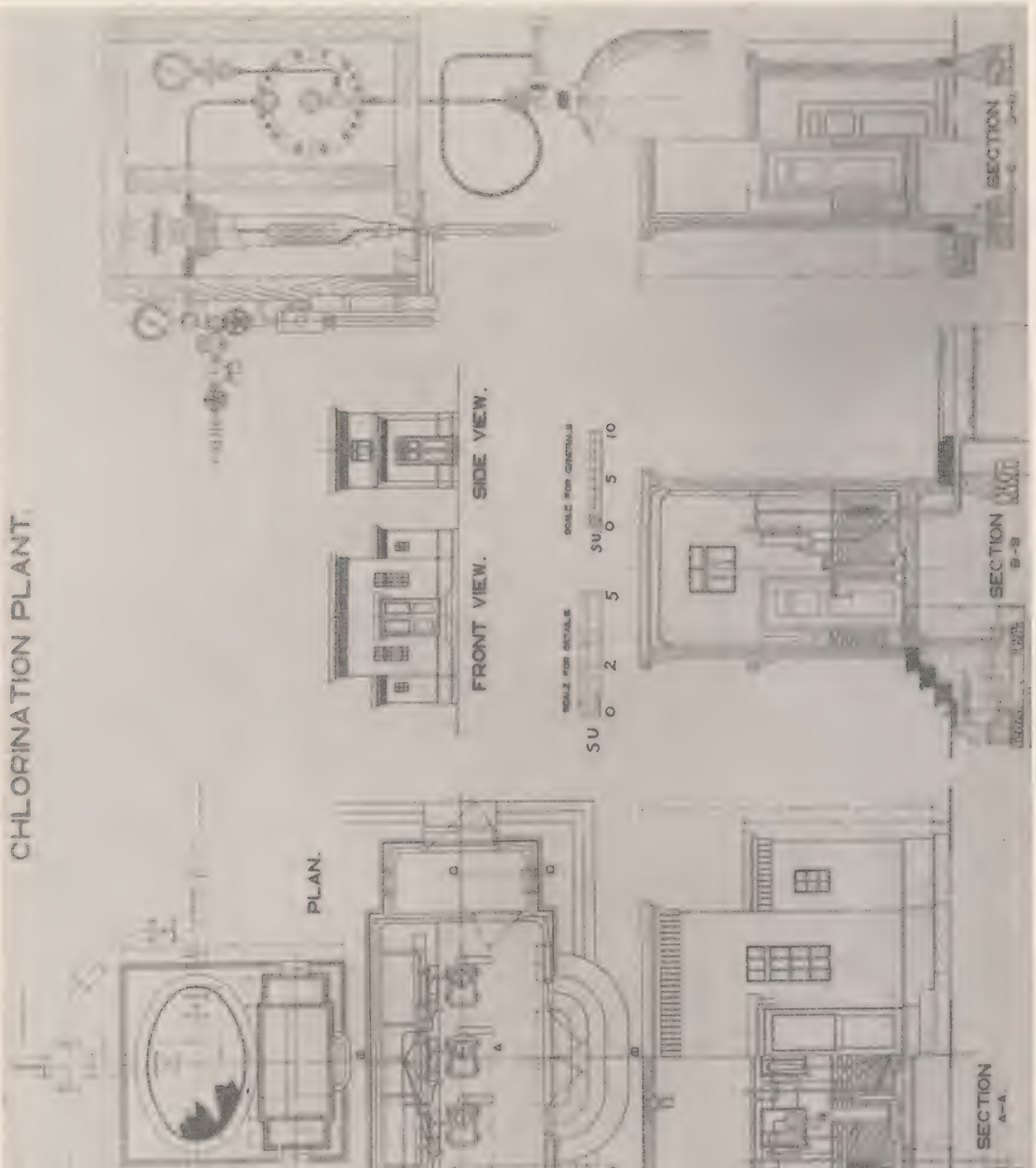
HIROSHIMA
FIG 27-XIII



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HIROSHIMA
FIG 26-XIII

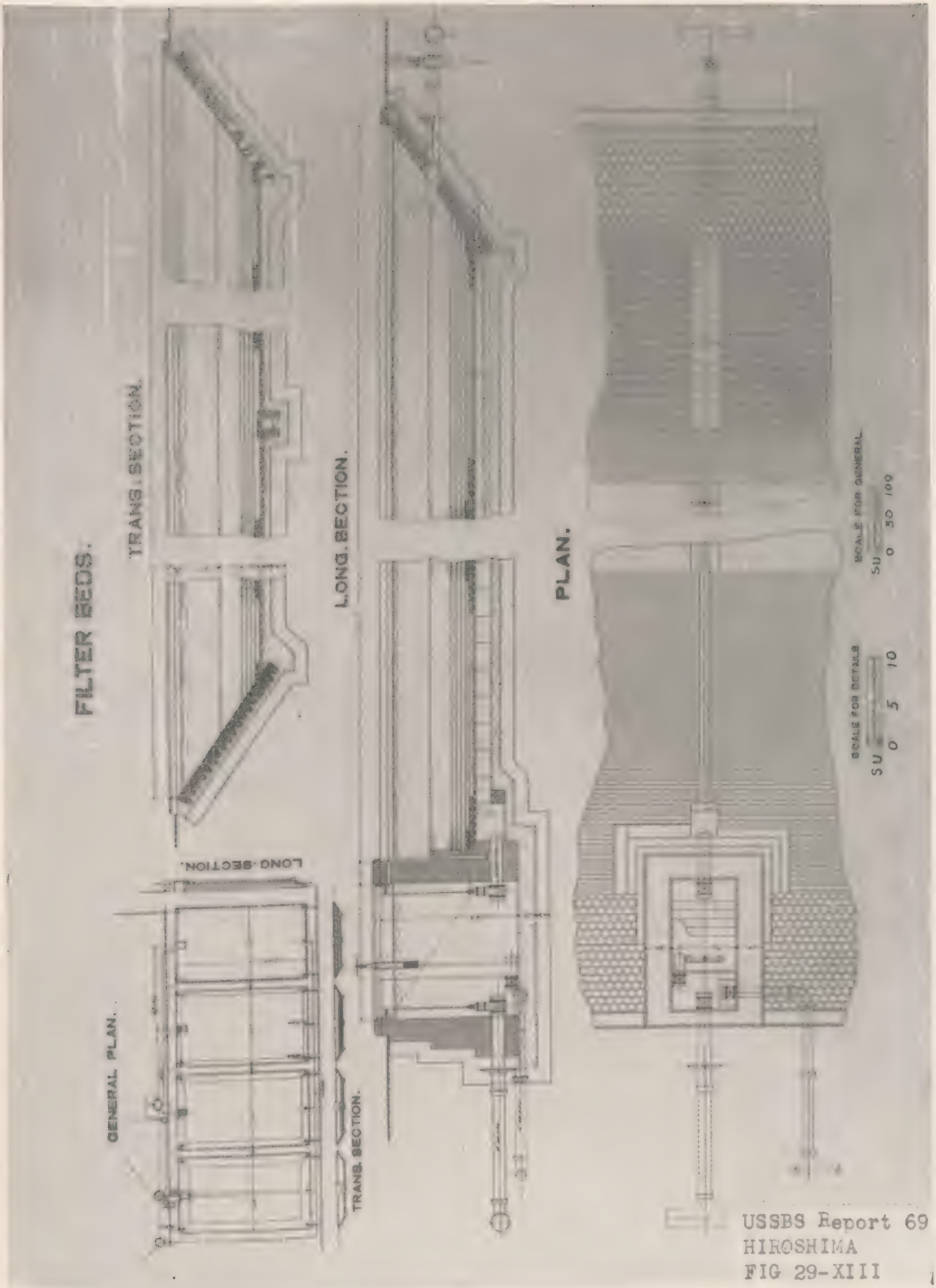

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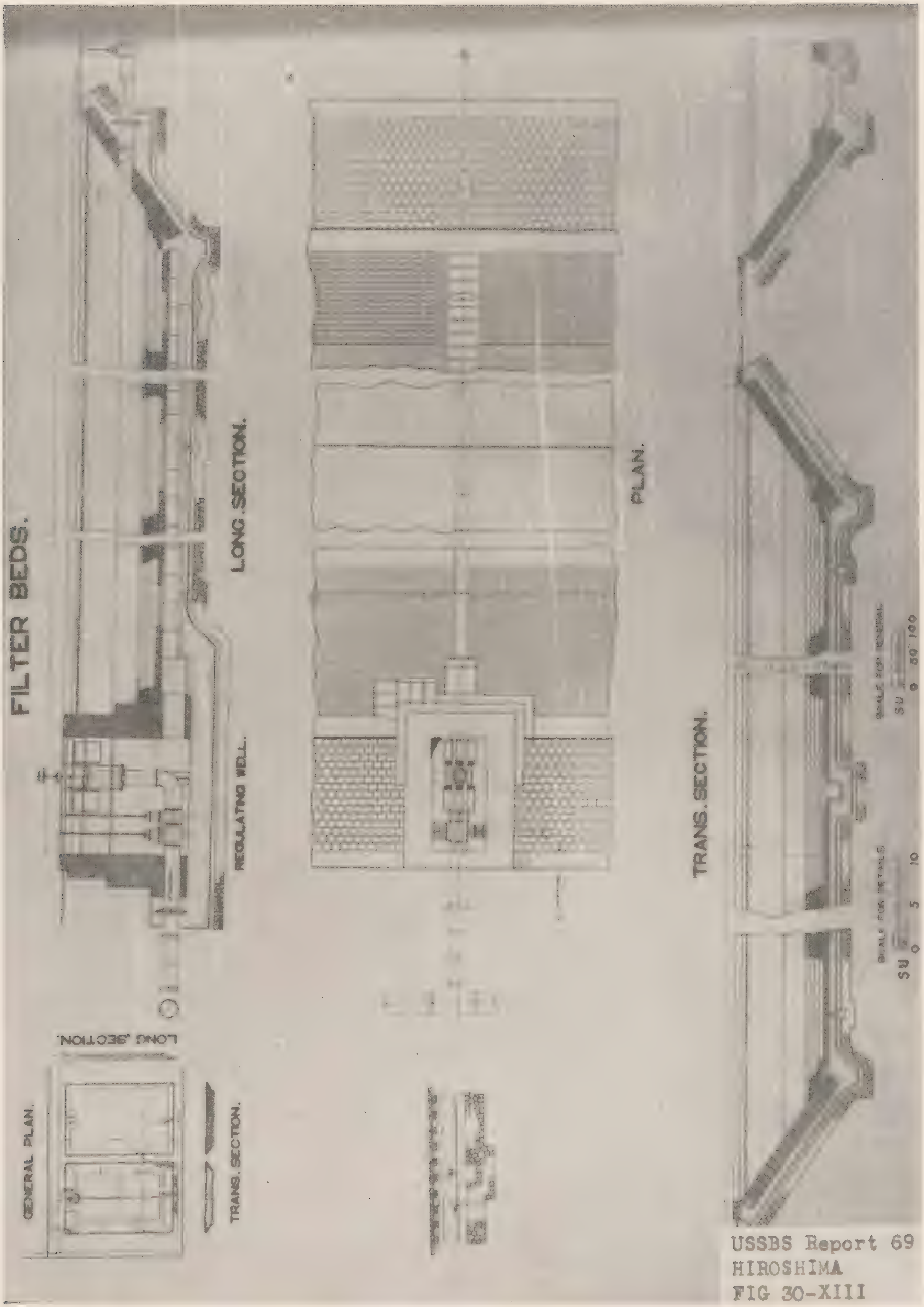
FIG 29-XIII



USSBS Report 69
HIROSHIMA
FIG 30-XIII

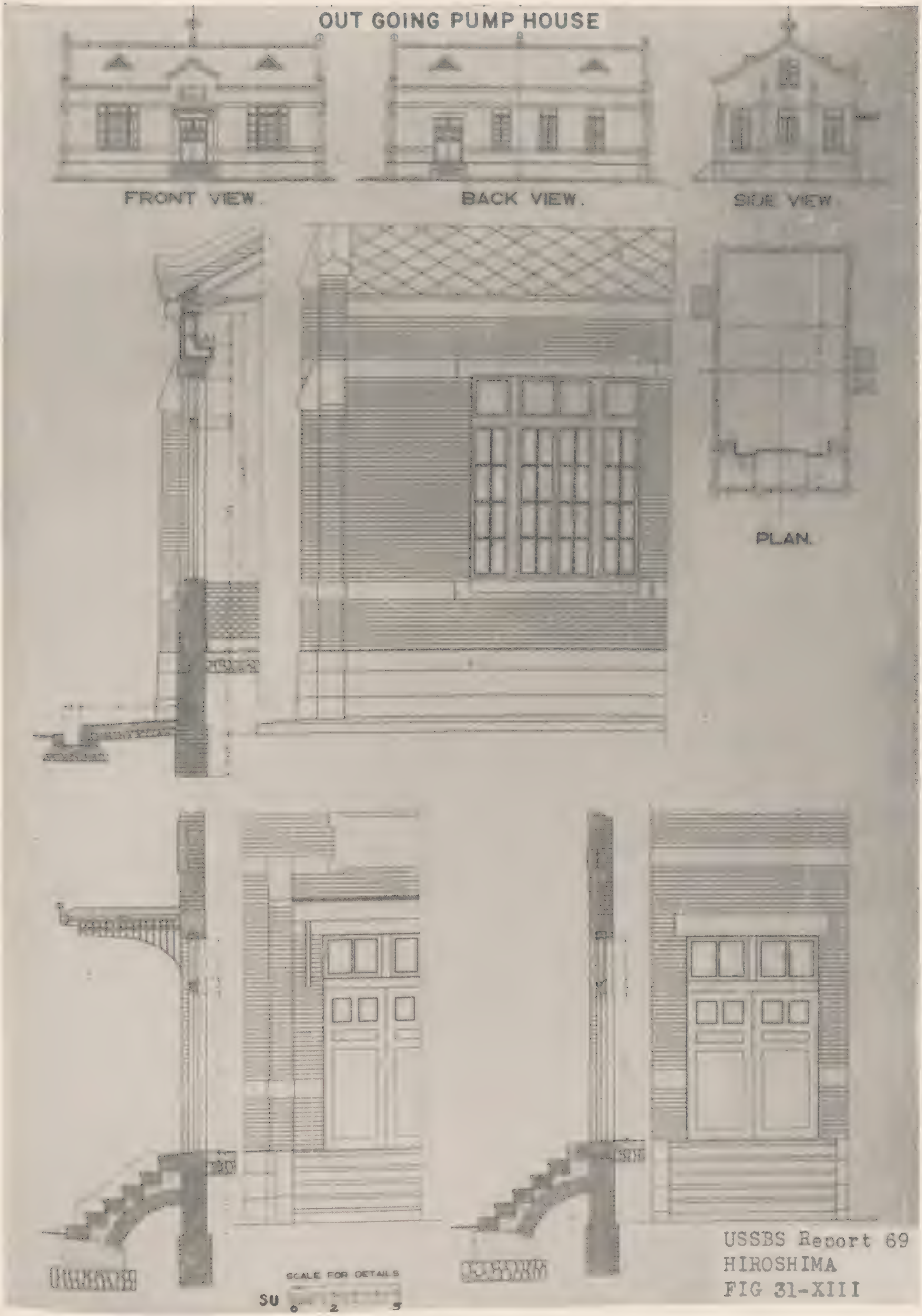


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FIG 31-XIII

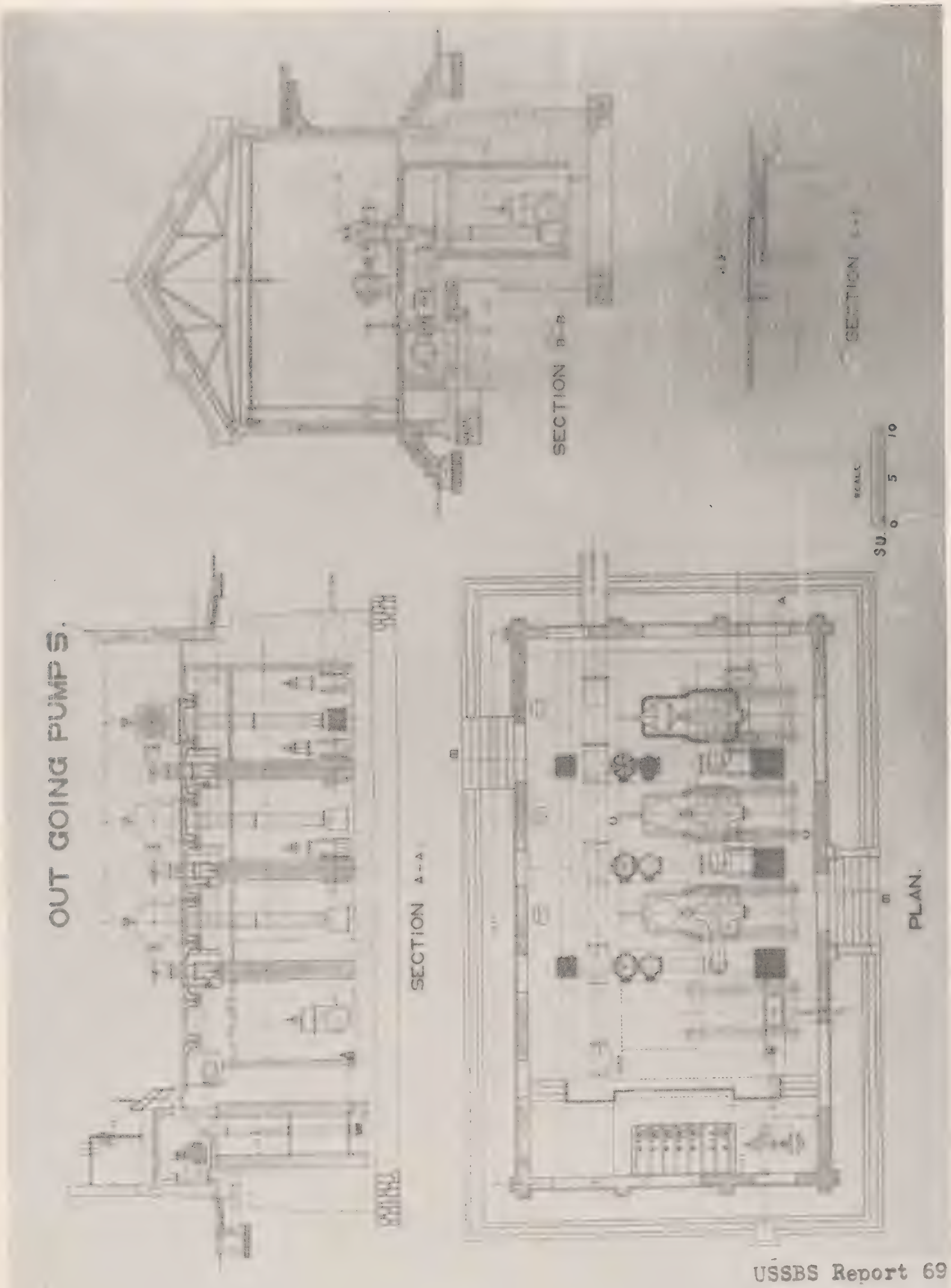

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FIG 32-XIII

j. All subsurface piping was standard 250 pounds per square inch, bell and spigot type, with the exception of connections to pumps, where screwed pipes and flanges were employed. Steel pipe of 250 pounds per square inch strength with flanged ends was used for connections within buildings.

k. A reservoir of 4,500,000 gallons capacity (Figs. 33 to 36 inclusive), located on a hill 165 feet above the purification plant, provided storage for filtered water prior to delivery. The reservoir was of reinforced-concrete design with an earth cover as detailed on Figures 33 and 36. The water-distribution system began at the reservoir and traversed the city (Fig. 16). Bell and spigot type, 250 pounds per square inch, cast-iron pipe of standard lengths was used for mains from 4 to 30 inches in diameter, the only exception being those mains attached to bridges where flanged connection and expansion joints were employed. Branches tapped from mains for dwellings varied in diameter from ½ to 1¼ inches, depending upon the size and use of the unit, and buildings were serviced with 2- to 4-inch-diameter, steel-screwed pipes, capable of withstanding a pressure of 250 pounds per square inch. Table 29 gives the length in linear feet of the cast-iron mains and laterals within the areas indicated on Figure 16.

TABLE 29.—*Water distribution mains and laterals*

Diameter (inches)	Length (feet)	Diameter (inches)	Length (feet)
30	10, 200	14	10, 500
24	1, 200	12	41, 100
22	15, 600	10	16, 200
20	12, 900	8	2, 400
18	15, 000	4, 5, 6, and 7	875, 000

All mains were buried 4 feet below ground elevation. Figures given by the water department of Hiroshima indicated pressures in the city center to be 40 pounds per square inch, with pressure at terminal points reduced to 5 pounds per square inch. The following numbered locations designate the pressure in pounds per square inch taken by actual test. (Fig. 16 shows locations of tests.)

The volumetric flow through the mains from the reservoir as determined by test was 4.9 second-feet for the 20-inch diameter pipe, 6.9 second-feet for the 22-inch diameter pipe, and 16.7 second-feet for the 30-inch diameter pipe, at a point approximately 6,000 feet from the manifold.

TABLE 30.—*Pressure in mains*

Location	Size of main (inches)	Pressure (pounds per square inch)
1	30	65
2	20	30
3	16	20
4	12	10
5	10	20
6	12	10

l. Each of the 12 water districts and 4 communities had from 10 to 12 valves. Gate valves rated at 250 pounds per square inch were placed at points where mains could be maintained against breaks or leaks. Two types of hydrants were used for fire protection, namely, standard or above-ground type (Photo 121), of which there were 2,000, and the flush or subsurface type, of which there were 2,200. In the congested areas hydrants were spaced at 600-foot intervals.

m. At the time data for this report was being compiled officials of the water department declared that full information could not be given as records had been destroyed. Three booster stations, however, as shown on Figure 16, were found. The Koi booster station did not augment the city water system pressure, but maintained pressures for the Koi area. This station had 30-horsepower, electrically driven pumps, each having an output of 3,600 gallons per minute. A water tower constructed of reinforced-concrete had a capacity of 234,000 gallons and acted as storage for the area. Booster pump stations 1 and 2, housed in wood-frame buildings of approximately 400 square feet each (Fig. 16), were of the same capacities as the Koi station but had no connecting water-tower storage. All equipment in these stations was of Japanese design and manufacture. A deep-well pump with a capacity of 1,500 gallons per minute was installed to supplement the normal water supply at the Army Divisional Headquarters. (Pump house equipment shown in Fig. 37.)

n. Because of the delta formation of Hiroshima numerous overcrossings were required to complete the water-distribution system (Fig. 16). The water department of Hiroshima constructed a crossing originally called the Kandabashi Aqueduct (Figs. 38 and 29), but it was destroyed by the flood of 1944, and the 20-inch water main was transferred to Bridge 10. Similarly, a wood aqueduct carrying a 14-inch main was destroyed by pre-

TABLE 31.—*Water distribution overcrossings*

Bridge No.	Grid	Bridge type	Length (feet)	Diameter (feet)	Constructed by—
3	5J	Concrete	276	16	Highway department.
5A (Enkobashi aqueduct)	5J	Steel truss	220	16	Water department.
7A (Sakaebashi aqueduct)	4I	do	289	22	Do.
10	3I	Concrete	307	20	Highway department.
12	5I	Plate girder	208	16	Prefectural government.
17	7H	do	544	12	Do.
19	6G	Concrete	259	18	Highway department.
20	6G	Steel I	276	16	Prefectural government.
22	5H	Plate girder	164	16	Do.
27	3G	Steel arch	200	10	Do.
29	5G	Steel truss	263	16	Do.
30A (Shinobashi aqueduct)	5G	do	350	16	Water department.
31	6G	Concrete	358	16	Highway department.
33	6F	do	410	16	Do.
37	5G	Plate girder	169	14	Prefectural government.
43	4F	Timber	410	14	Do.
48	4E	Plate girder	240	12–14	Do.

vious floods and the main was transferred to Bridge 43. The Enkobashi Aqueduct shown on Figures 40 and 41, the Sakaebashi and the Shinobashi Aqueducts, Figures 42, 43, and 44, are included in this report as Bridges 5A, 7A, and 30A respectively. The overcrossings or aqueducts are listed as follows in Table 31 which was taken from the Bridge Damage Section.

o. In 1943 efforts were made to camouflage water distribution equipment, but the camouflage was not maintaned. At the purification plant wires were strung over the settling basins and filter beds to support netting and garlands, and shrubs and branches were placed on the reservoir earth cover. A bamboo and net cover was placed around the Koi water tower.

3. Analysis of Damage

a. The damage to the pumping station (Photo 107) and purification plant (Photo 108), buildings and equipment (Photos 109, 110, and 111), 14,000 and 9,200 feet from GZ, respectively, on 6 August 1945 can beconsidered as negligible. All damage suffered by buildings (Photo 112) and equipment was by blast. No fires started in this area. Glass panes in all buildings were broken by the blast, as well as window frames, doors, and door frames. Some roof stripping occurred on Buildings 3, 4, and 6 (Photo 113). Sidewall damage occurred to Building 8. All building damage is indicated on Table 28.

b. Splinters of glass from broken window panes in Building 4 entered the rotor cage of one motor while it was in operation and the motor shirt-circuited and burned out as a result. The metering equipment in Building 5 (Photo 114) suffered heavy damage by blast, but the use of the valve system was not impaired.

c. Due to a short circuit in the high-tension, 22-kilovolt lines leading to the Suigenchi electric substation, power was cut off immediately. No damage occurred within the substation. The power cut-off stopped the pumping stations but, after examination of the pumping station and purification plant revealed no damages, the auxiliary generator was started. Water was pumped and filtered from power supplied by the auxiliary generator from 6 August 1945 until 9 August 1945.

d. The intake (Photo 115), settling basins, filter beds (Photo 116), and reservoir were undamaged. No leaks in piping or mains to or from the intakes, settling basins, filterbeds and the reservoir had been detected. The water in the reservoir, however, dropped to a seriously low level because of leaks in pipes within the city.

e. Building and equipment damage is summarized in Table 28. With the exception of Bridge 29, which will be discussed in another paragraph, 8 leaks in the water-distribution system (Fig. 16) were found by the water-department officials and were attributed to the blast effect of the atomic bomb. After inspection of leaks 1, 2, and 3 (Fig. 16) in the 16- and 18-inch mains, it was found that leak 1 (Photo 117) was in a 4-inch diameter, cast-iron lateral, directly over a 16-inch main, broken at the valve body by a falling 19-inch brick wall from an adjacent building. Leak 3 (Photo 119)

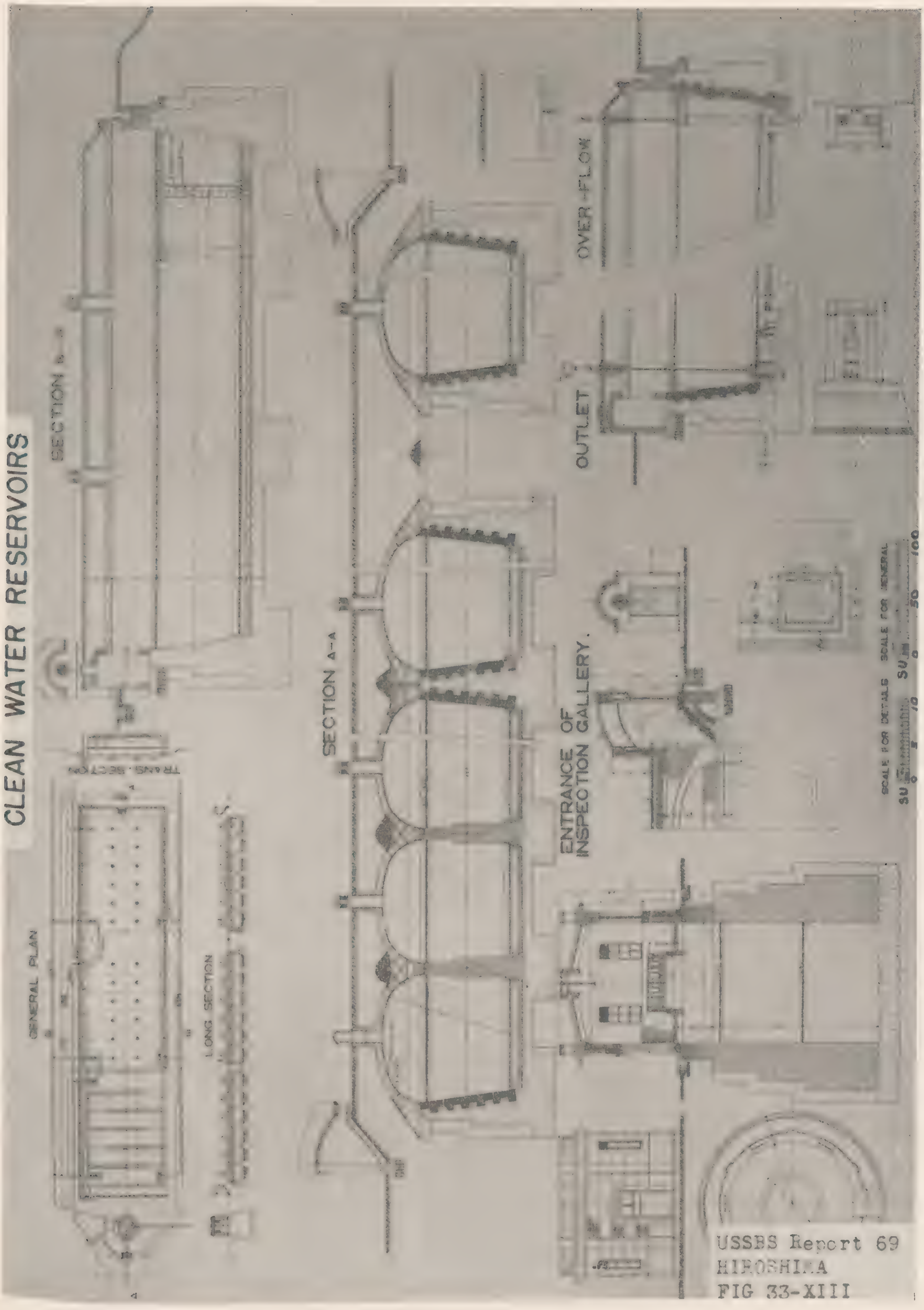

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FIG 33-XIII

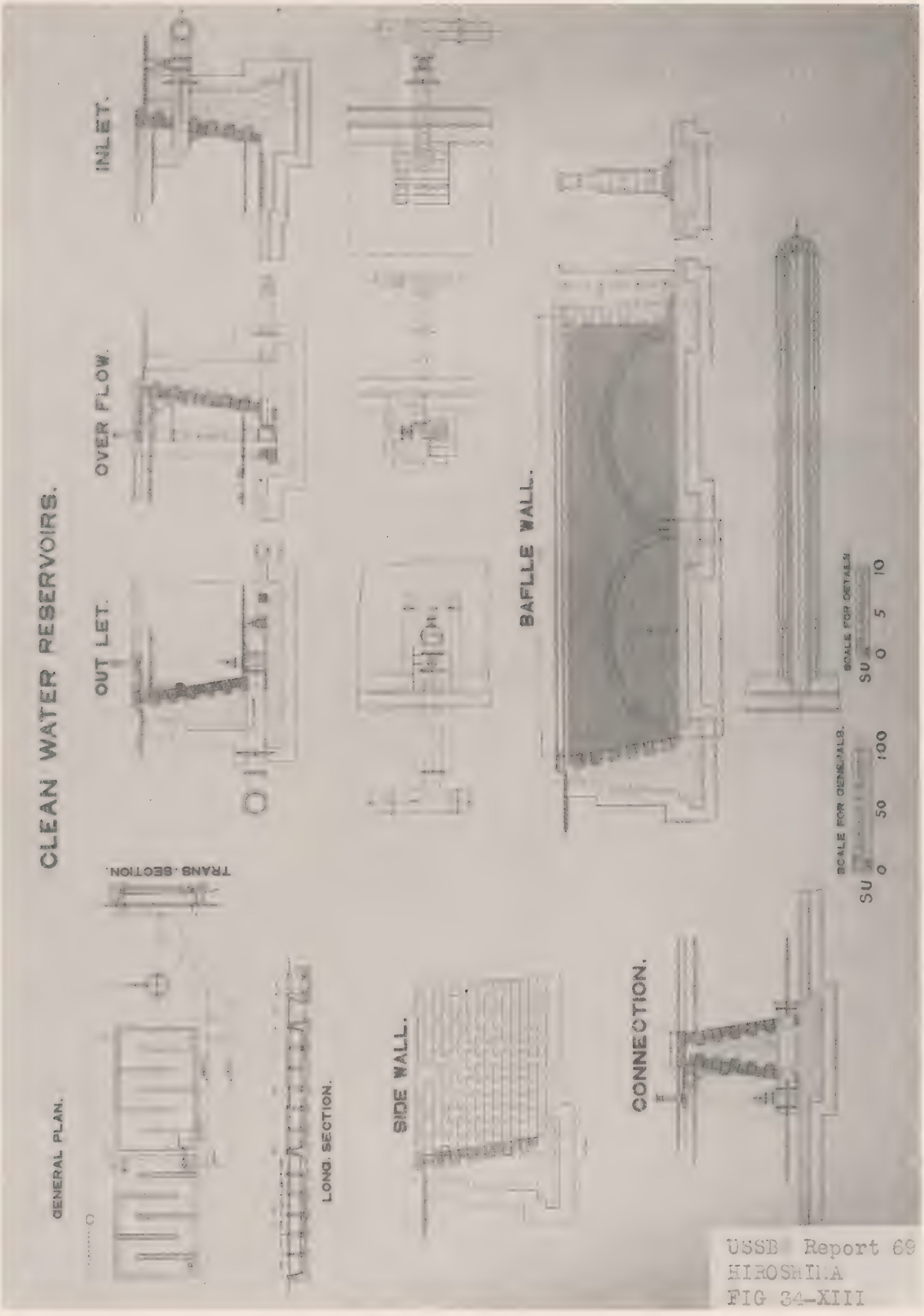

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FIG 34-XIII

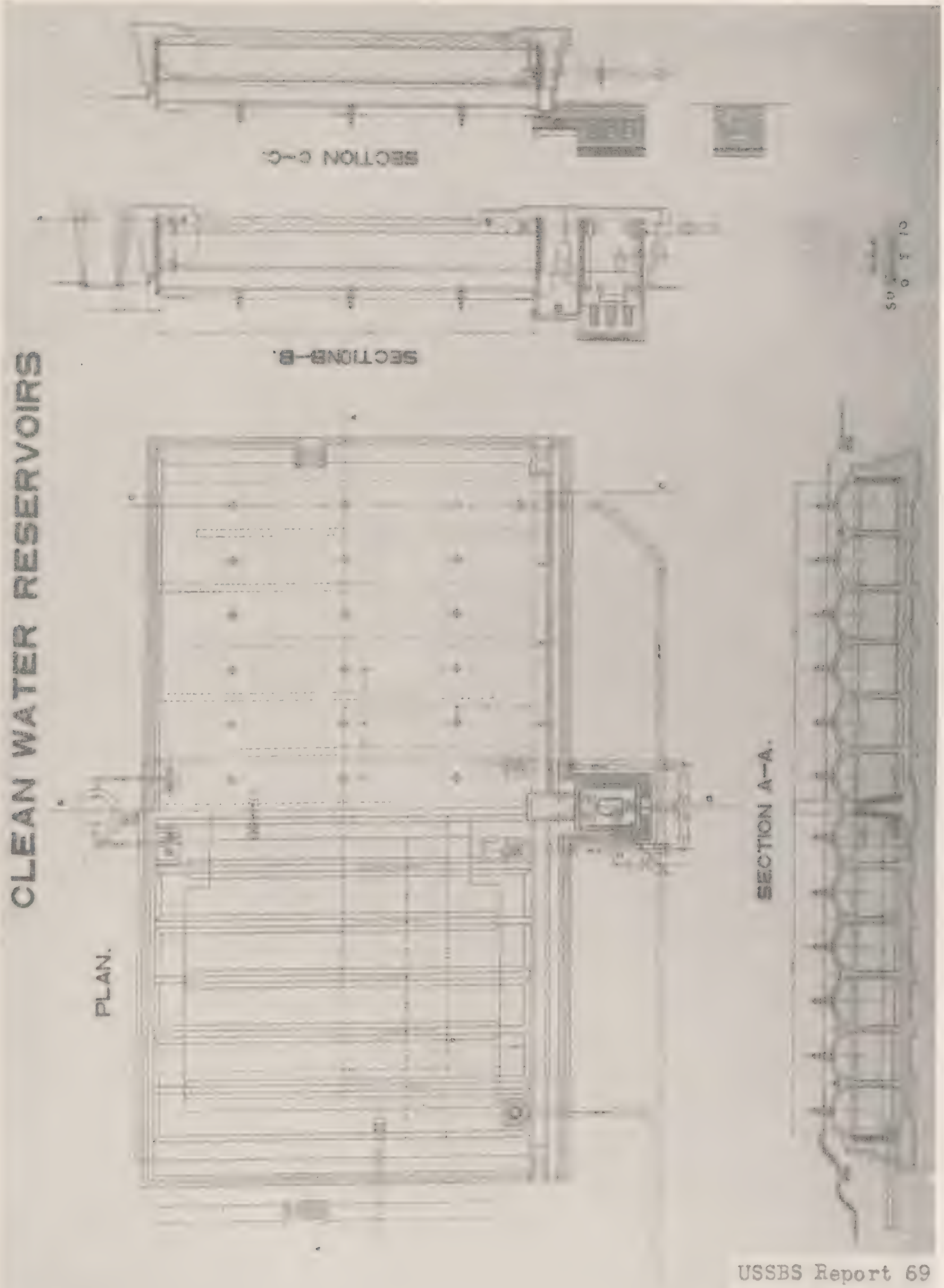

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FIG 35-XIII

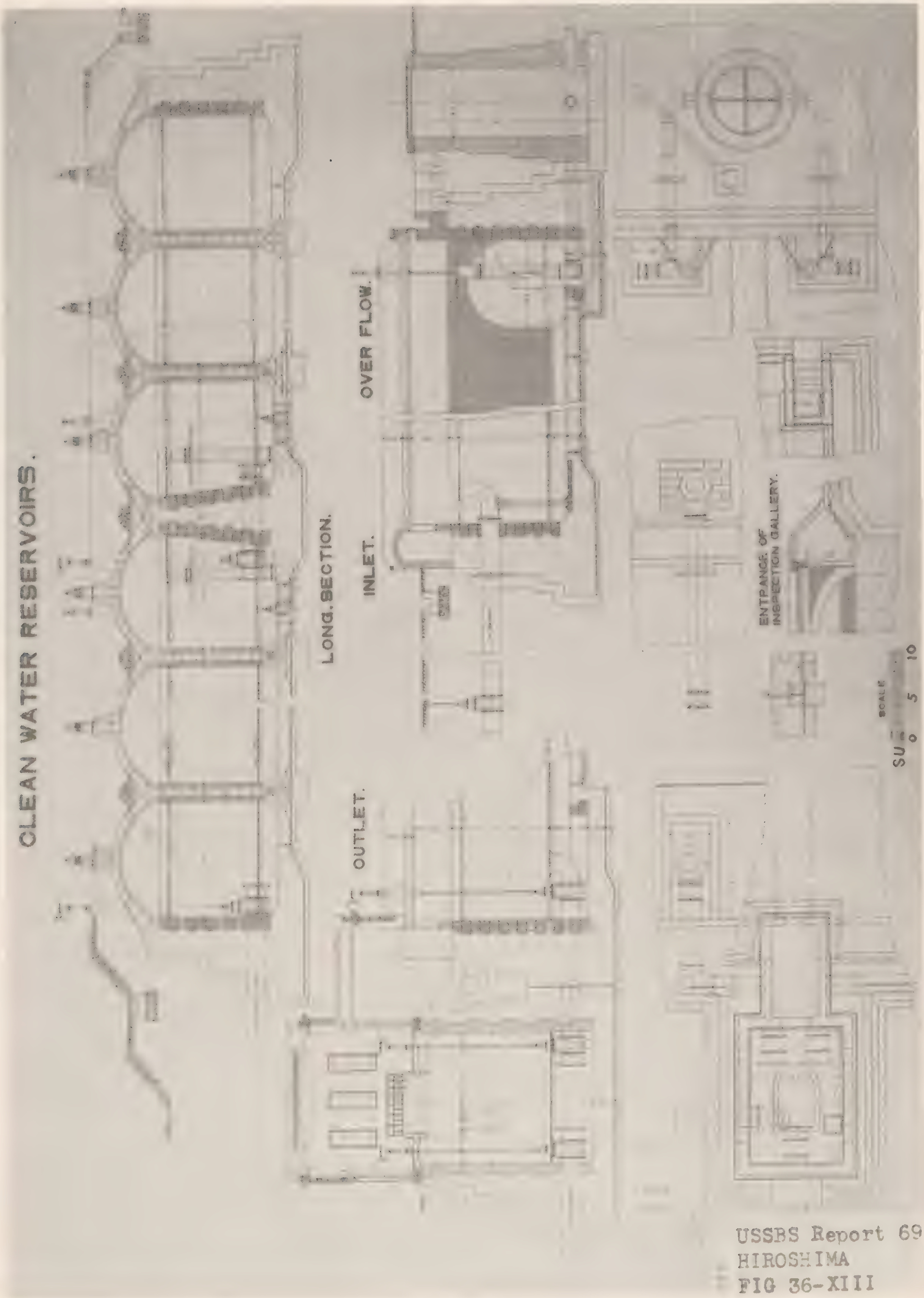

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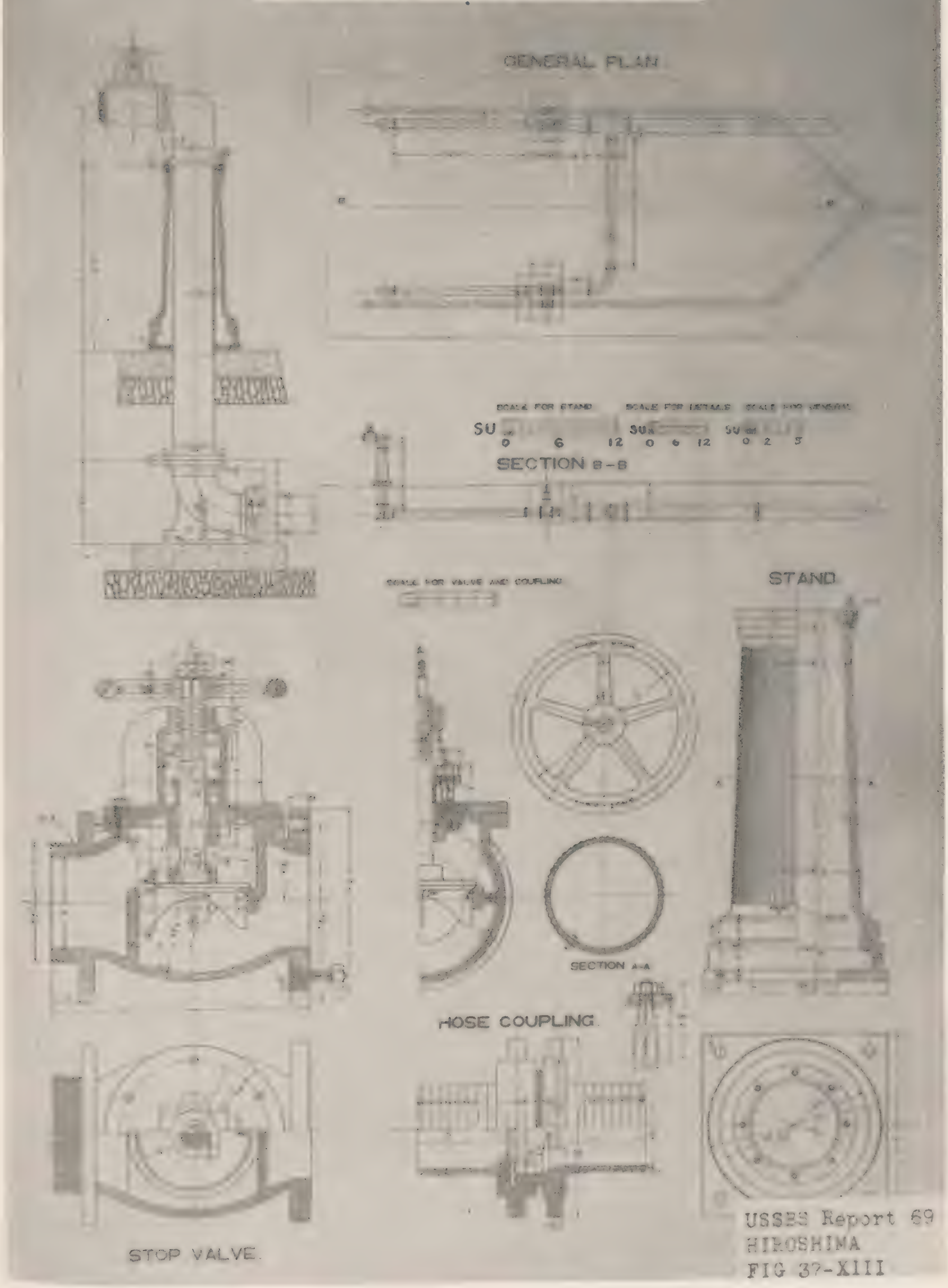
FIG 36-XIII

MILITARY SUPPLY PLANT



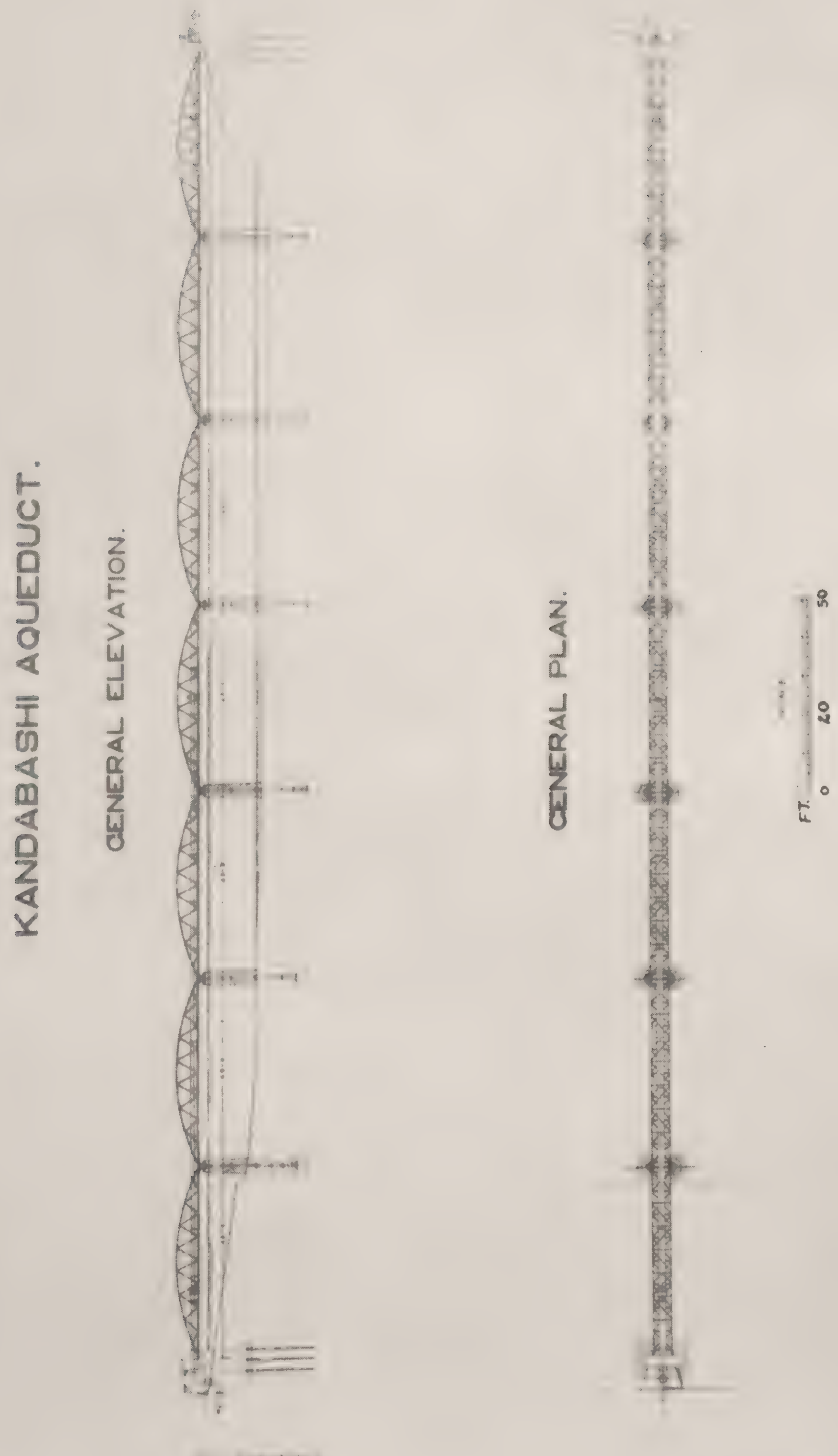


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FIG 38-XIII

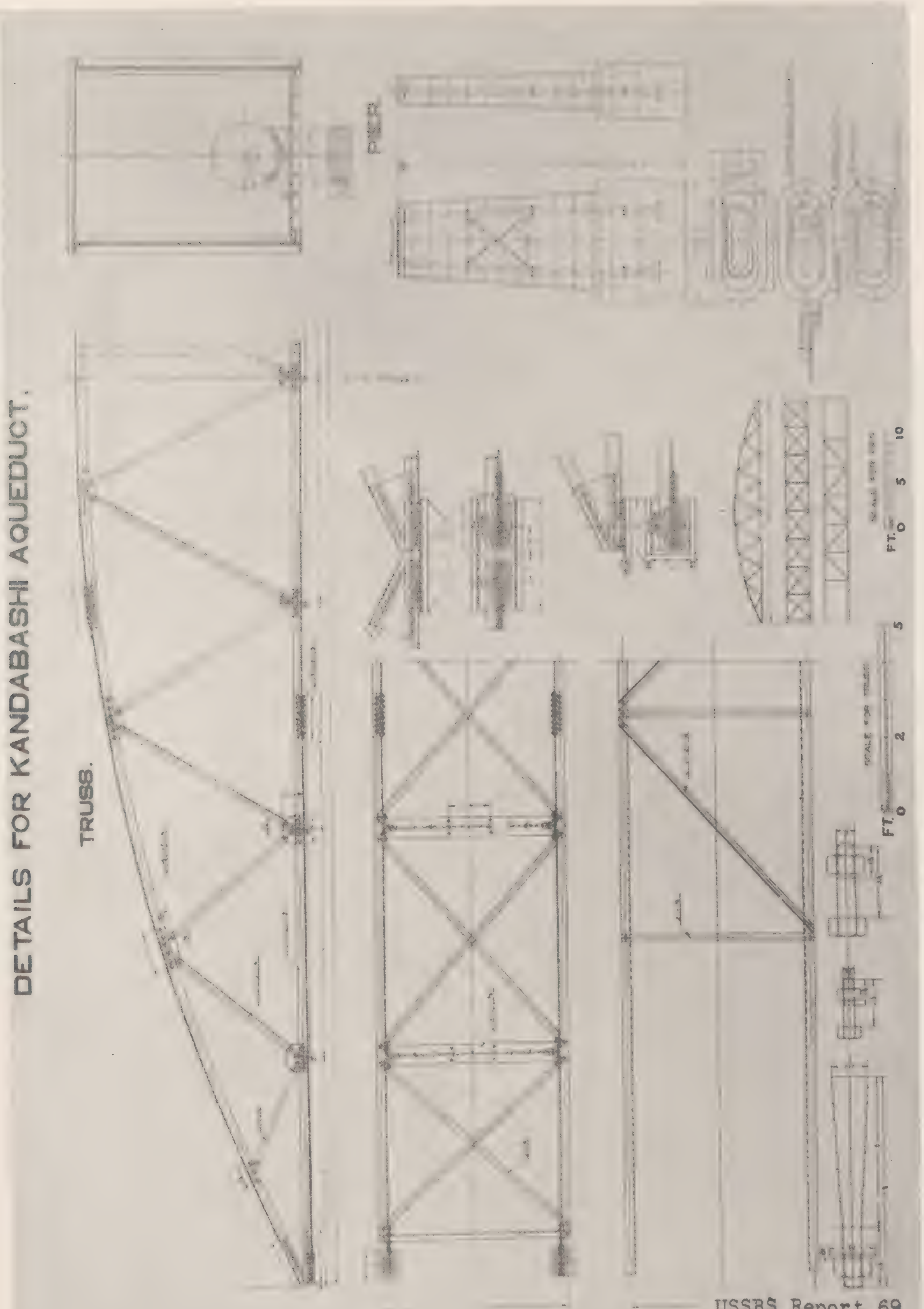

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FIG 39-XIII

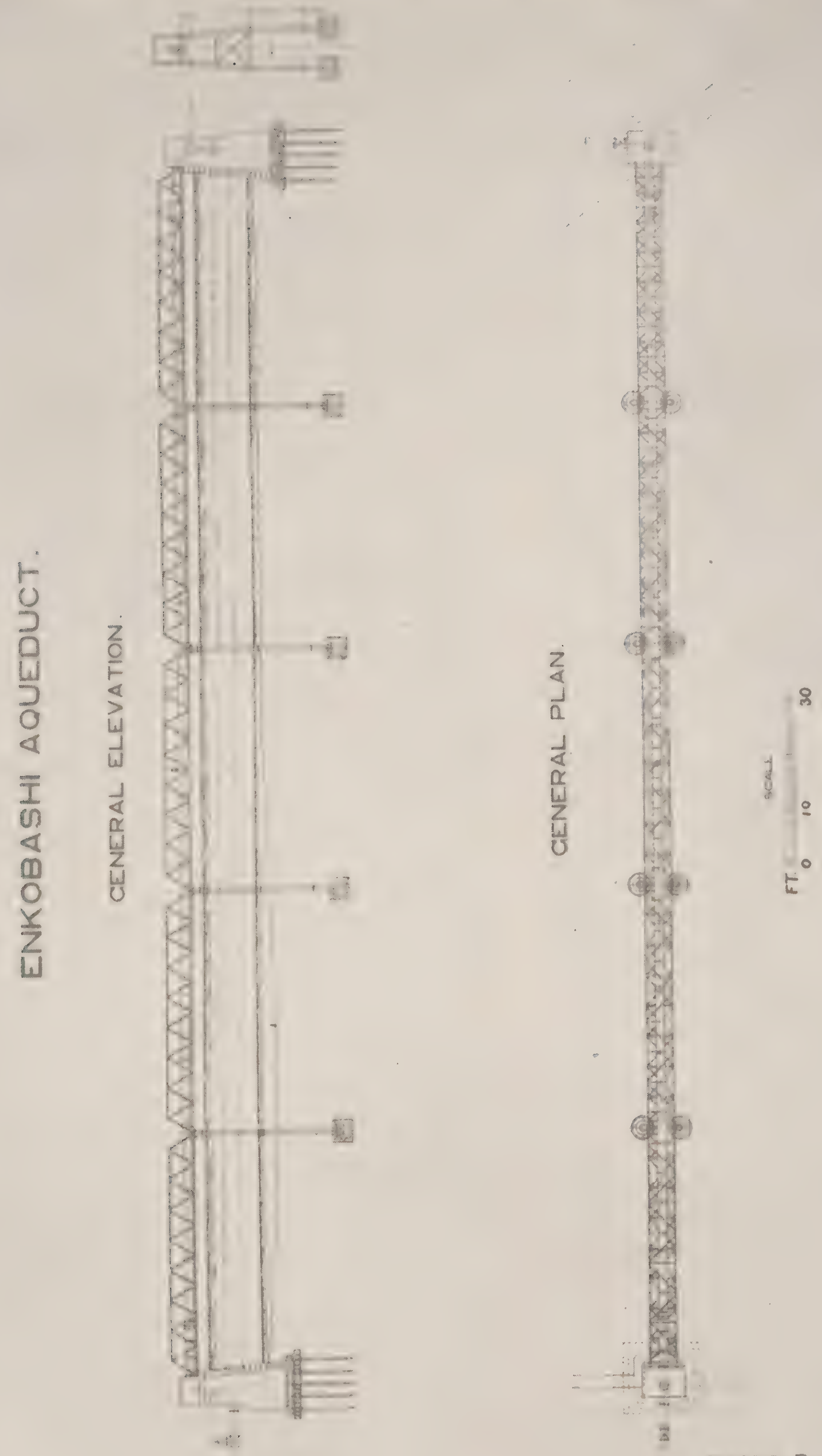

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FIG 40-XIII

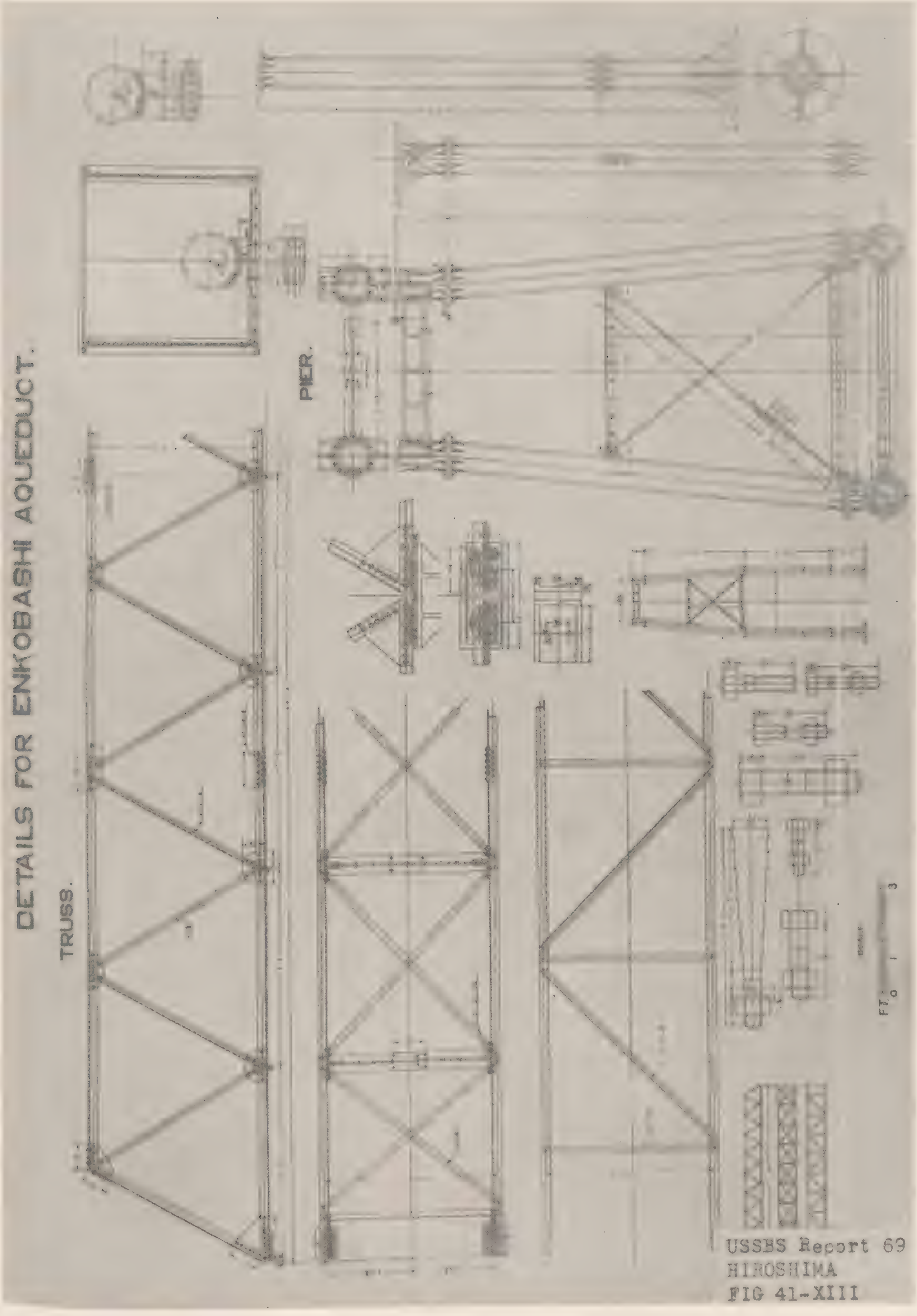

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FIG 41-XIII

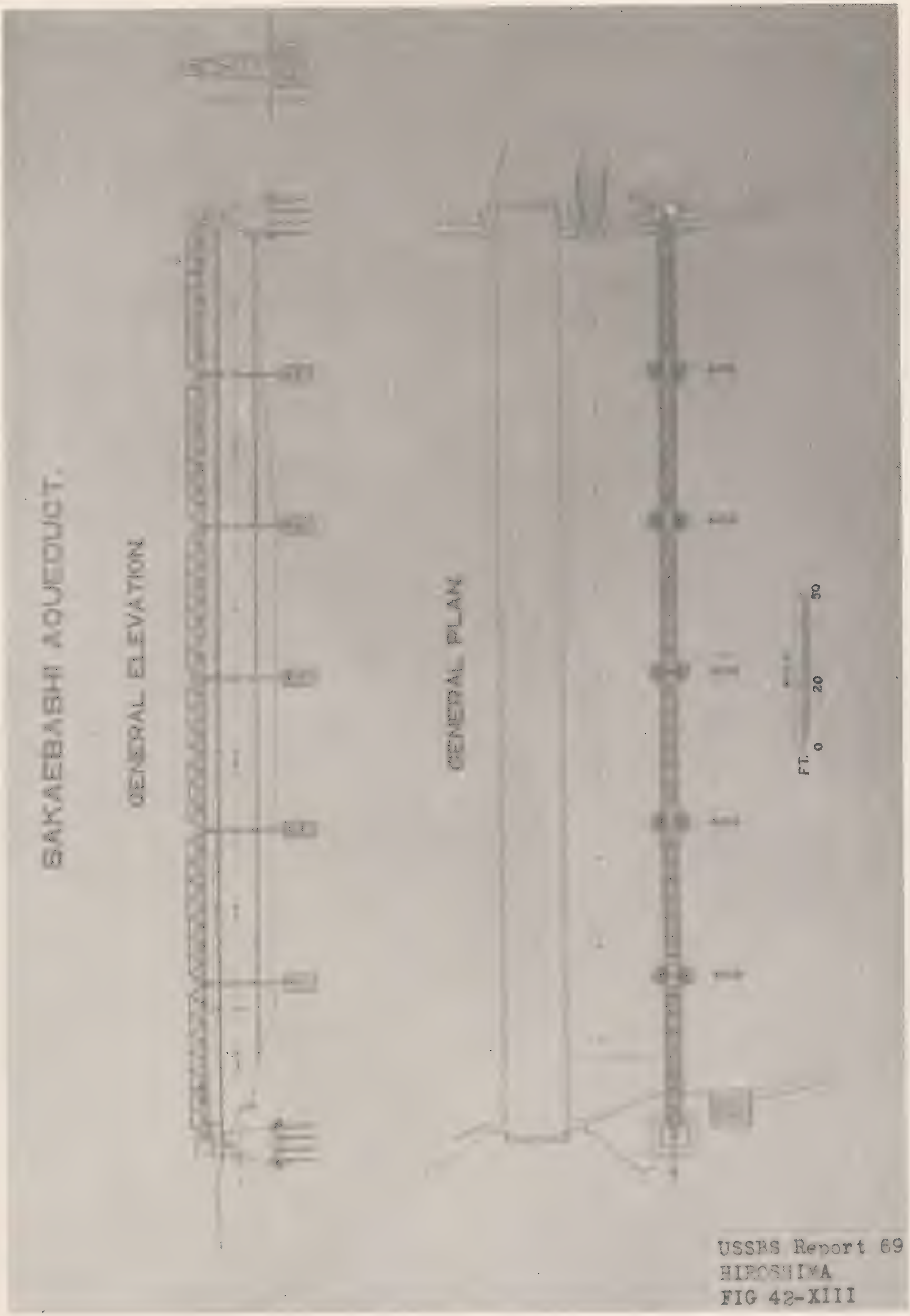

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FIG 42-XIII

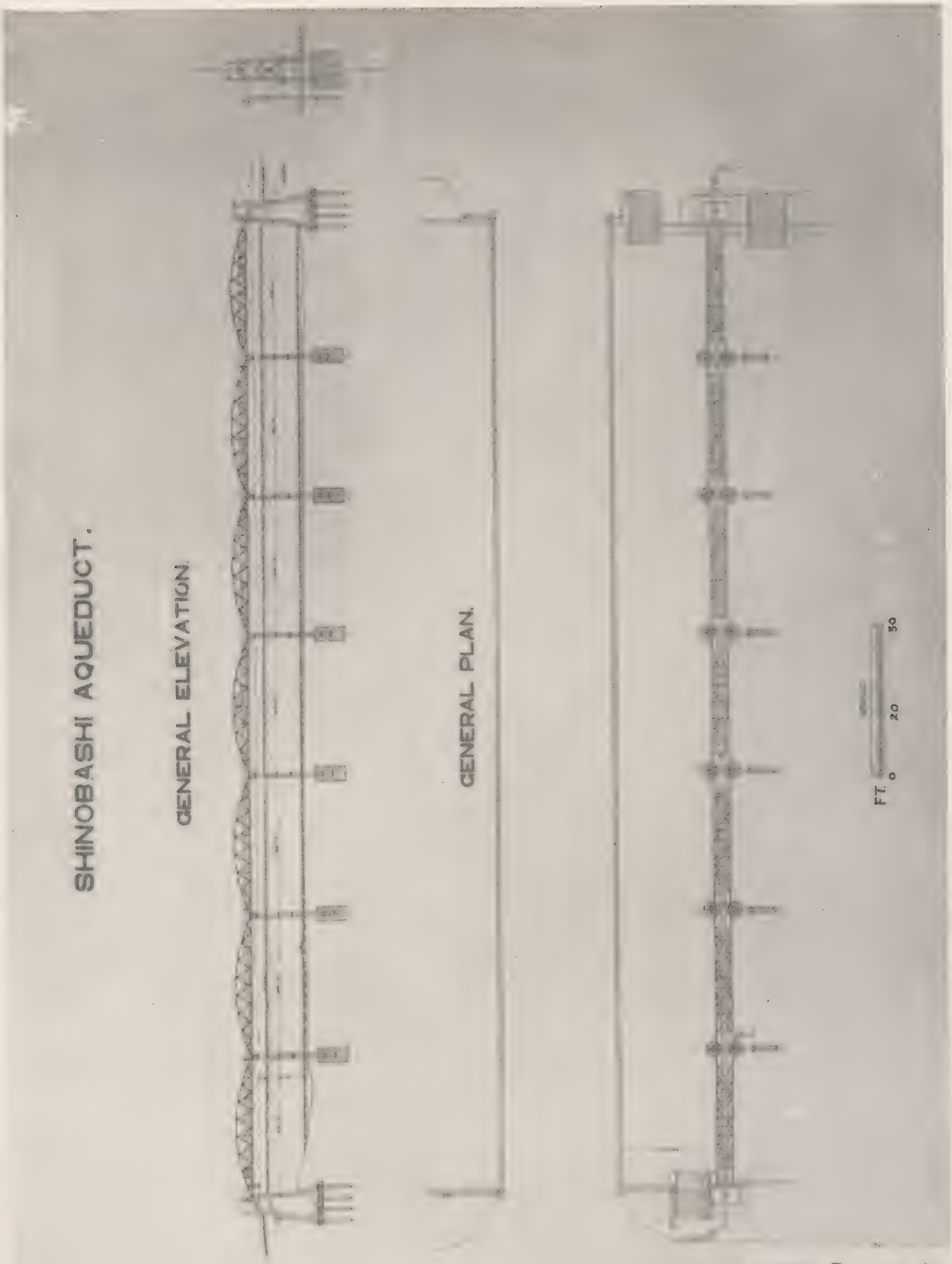

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FIG 43-XIII

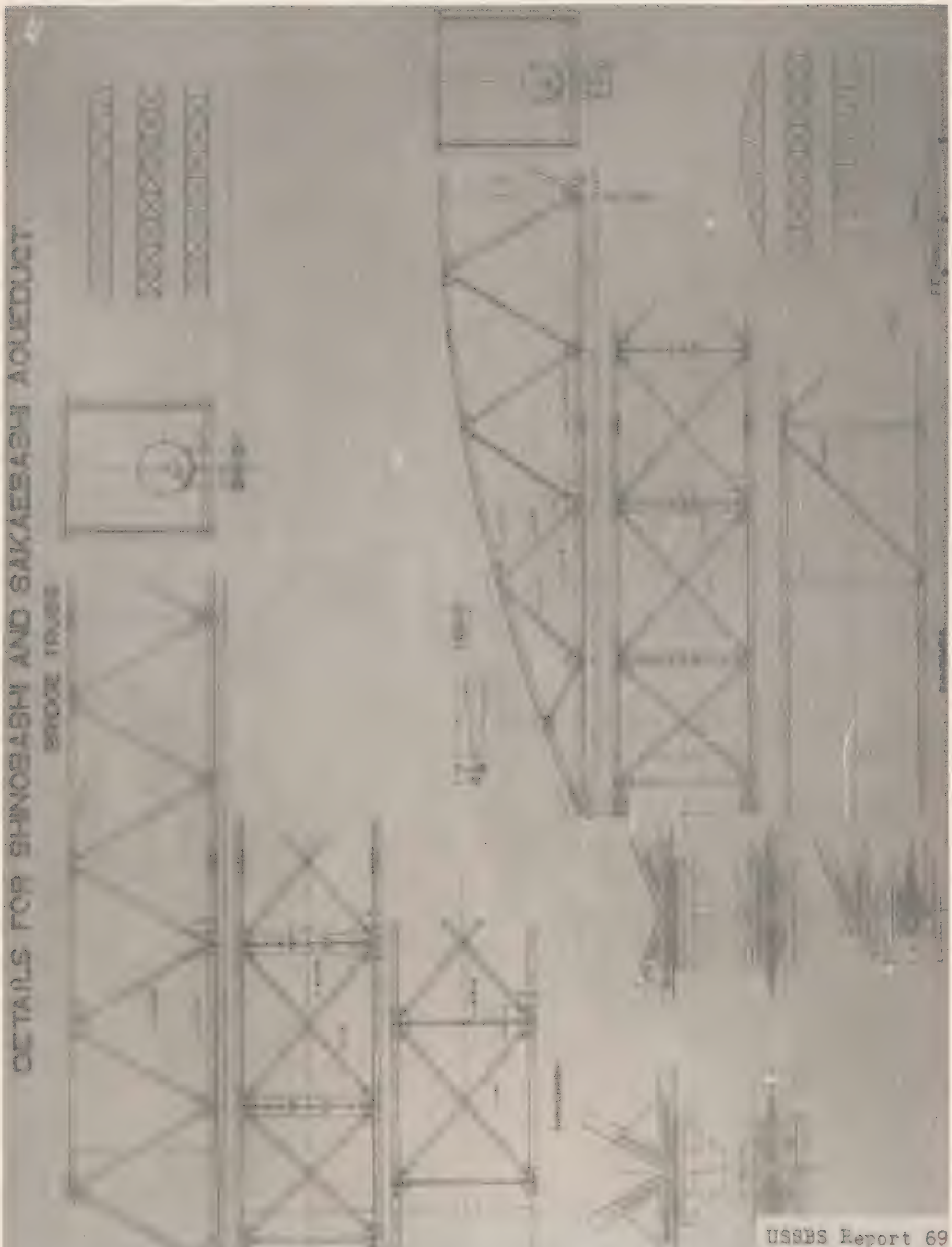

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FIG 44-XIII

PHOTO 107–XIII. Pumping station Building, 14,000 feet from GZ. Windows broken by blast.

PHOTO 108–XIII. Diesel pumping plant, Building 3, 9,000 feet from GZ, showing window frames damaged by blast.

PHOTO 109–XIII. Equipment and electrical panel at pumping station, 14,000 feet from GZ.

PHOTO 110–XIII. Diesel pumping plant, Building 3, showing pumping equipment, 9,000 feet from GZ.

PHOTO 111–XIII. Undamaged pumphouse, Building 6, equipment and switch board panel, 9,000 feet from GZ.

PHOTO 112–XIII. General view of purification plant showing buildings, filter beds, and reservoir, 9,000 feet from GZ.

PHOTO 113–XIII. Pumphouse, Building 6, showing light roof stripping. Note electrical substation, 9,000 feet from GZ.

PHOTO 114–XIII. Damaged meter and recording equipment in Building 5, 9,000 feet from GZ.

PHOTO 115–XIII. Intake system on the Ota River, 14,300 feet from GZ.

PHOTO 116–XIII. Filter beds being processed. Note roof stripping on Building 6, 9,000 feet from GZ.

PHOTO 117–XIII. Leak 1. Four-inch gate valve broken by debris from 19-inch brick wall, 1,100 feet from GZ.

PHOTO 118–XIII. Leak 2, 100 feet from GZ. Lead-caulking seal broken in 16-inch main; 4-inch main undamaged.

PHOTO 119–XIII. Leak 3. Street L cracked by building movement, 600 feet from GZ.

PHOTO 120–XIII. Leak 4 caused by falling debris, 3,100 feet from GZ.

was a cracked street L connected to a 7-inch lateral damaged by the movement of the building serviced, and leak 2 (Photo 118) was a break in the lead-caulked seal of an 18-inch main, which could have been caused by the bomb blast, as the main was only 100 feet from GZ, but, in view of the severe action induced in Bridge 22 by the blast, it is more probable that the bridge movement caused this leak, otherwise, a series of leaks would have occurred from the bending action in the mains, occasioned by blast pressure. There was no crushing of the mains at any place. Leaks 4 (Photo 120) and 5 were also caused by falling debris but leaks 6, 7, and 8 did not result from the atomic-bomb attack. It was estimated that 70,000 branches or leads were damaged as a result of blast or fire damage to dwellings and other buildings. Because of the great number of open pipes the pressure of a normally low-pressure system dropped to zero.

f. With the exception of one valve, referred to previously, all valves were undamaged. A few standard, above-ground hydrants (Photo 121) were damaged by falling debris but no flush-type hydrants (Photos 122 and 123 were damaged. Because of the great number of damaged branches, however, residents pushed the balls of the flush-type hydrants from the seats allowing water to flow for their personal use (Photo 123). After all leaks had been closed off in mains and laterals and in all branches or leads that could be reached, the distribution pressure within the city was brought up to 15 pounds per square inch, but even then 16,000,000 gallons of water per day were required to supply the city. As there were no requirements for water in the city center, that part of the system was discontinued.

g. The booster pump station at Koi, 8,000 feet from GZ, was undamaged. Buildings at stations 1 (Photo 124) and 2 (Photo 125) however, 6,600 and 5,600 feet, respectively, from GZ, received structural damage by blast. Apart from the electrical panel damage, no other equipment damage resulted from the blast. The pumping station at the Army Divisional Headquarters, 4,600 feet from GZ, sustained the same amount and type of damage as booster pump Stations 1 and 2. No effort had been made to place the booster pump stations or the Army headquarters pump station in operation.

h. Bridge 29 (Photo 126), referred to in a preceding paragraph, was the only bridge acting as a water crossing (Photo 127) that was totally damaged directly by blast. This damage did not deprive the area west of the Ota River of water since there was another 16-inch crossing within the same loop. Bridge 43 (Photo 130) was damaged by blast and fire, depriving of water the section served by it. Bridge 43 was repaired in October 1945. There was some movement in Bridge 22 caused by blast which broke the seal of leaks (Fig. 16) but not sufficiently to cause interruption of any service. The angle-chord members of Bridges 30A (Photos 128, 129) were twisted by the blast, but the 16-inch main was undamaged and no leaks were noted. The floods of 17 September 1945 and 5 October 1945, however, damaged four bridges (Photos 131, 132, and 133) to such an extent as to impair their use as water overcrossings. The following Table 32 is a summary of bridge damage as given by the Bridge Damage Section:

It will be noted that more damage resulted from the floods than from the atomic-bomb attack.

i. The cost of damage to the water system as of 15 November 1945 was estimated at 3,000,000 yen, or $750,000 at the rate of exchange of 4 yen to a dollar.

4. Remarks

a. The city of Hiroshima maintained an adequate, modern water supply system, capable of furnishing 20,000,000 gallons of water a day. The system was of rather recent design, and stand-by units were installed to prevent any interruption in the service. At the time of the attack the source of power supply was actually cut off and the stand-by units were utilized to supply the city. The equipment at the pumping stations and the purification plant was not damaged enough to discontinue service. Thus, it can be seen that stand-by units are essential, and failure of the main unit need not halt operations altogether.

b. The 250-pounds-per-square-inch pipe, buried 4 feet below ground elevation, proved to be of adequate strength to withstand an attack of the type to which Hiroshima was exposed. Damage to the dwellings and buildings resulted in considerable leakage from the water branch pipes extended to them, thereby reducing the water pressure below normal working pressures. This hampered fire fighting. Because of the vulnerability of buildings and dwellings to an atomic-bomb attack, branches connecting buildings with the mains would be

TABLE 32.—*Bridge damage*

Bridge No.	Dist. from GZ (feet)	Type	Diameter of pipe (inches)	Damage	Cause
3	7, 130	Concrete	16	Severe	Flood.
5A	6, 160	Steel truss	16	None	
7A	5, 240	do	22	do	
10	6, 950	Concrete	20	Moderate	Do.
12	4, 700	Plate girder	16	None	
17	7, 600	do	12	do	
19	4, 270	Concrete	18	do	
20	2, 900	Steel I-beam	16	do	
22	260	Plate girder	16	do	
27	4, 360	Steel arch	10	do	
29	1, 190	Steel truss	16	Complete	Blast.
30A	1, 880	do	16	Slight	Do.
31	4, 540	Concrete	16	Severe	Flood.
33	5, 300	do	16	do	Do.
37	3, 220	Plate girder	14	do	Do.
43	5, 200	Timber	14	do	Blast and fire.
48	7, 130	Plate girder	12–14	None	

damaged in approximately the same degree as the structure. This would hold true regardless of the locality of the attack.

c. Two booster pumping stations were installed at the locations shown on Figure 16 to overcome friction losses in the water supply system. Because these booster stations were improperly placed and were inadequate in capacity, the system pressure within the city varied from 30 to 10 pounds per square inch (Table 31). Any leaks in the system tended to reduce the pressure to zero for practical purposes. The structures housing these units were of flimsy construction and offered too little protection to the electrical-panel distribution controls. These vulnerable points made the system useless at the time it was most needed. To protect the booster pump stations and insure constant pressure in the mains, heavy, reinforced-concrete structures would be required, as well as shock-resistant electrical distribution panels. A subsurface, electrical distribution system, referred to in Part C of this section would greatly enhance the chances of continued operations of the booster stations in case of an atomic-bomb attack.

d. The damage by blast to Bridge 29 interrupted the service of the 16-inch water main that crossed the Ota River at that location, but other crossings in the same area and in the same loop assisted in supplying water to the area. The twisted members of Bridge 30A indicated that considerable damage was received. Had it not been that the strength of the structure was augmented by the 16-inch water main, it probably would have been further damaged. The structures used as water crossings were not damaged sufficiently to put the system out of service, but, in the event of larger bombs, this type of crossing may not be able to withstand blast pressures developed. In view of future possibilities, structures such as Bridge 30A, being near to total damage after exposure to the atomic-bomb attack of 6 August 1945, must be considered inadequate for use as river-crossing aqueducts.

F. SANITARY AND STORM SEWER SYSTEM

1. Summary

a. Waste Water. Because of the delta formation of Hiroshima, short laterals to the branches of the Ota River were used to dispose of 80 percent of the residential waste water, while the remaining 20 percent was carried through branch pipes to the sewer mains.

b. Disposal of Excrement: The lack of natural or artificially produced fertilizer in Japan necessitated the collection of human excrement as a substitute. To make this fertilizer available to the farmers on the neighboring islands, the city of Hiroshima made collections from 70 percent of the city area. Charges of 50 sen were made to the residents and 30 sen to the farmer for each 72 of the 130,000 liters per month collected. Collections from the remaining 30 percent of the city, comprising the outskirts, were made by farmers on the mainland.

PHOTO 121–XIII. Standard-type hydrants. Lower view, damaged by debris, 3,600 feet from GZ.

PHOTO 122–XIII. Flush-type hydrant with operating rod. Damaged in warehouse fire.

PHOTO 123–XIII. Residents using water from flush type hydrant, when ball valve was pushed from seat, 3,500 feet from GZ.

PHOTO 124–XIII. Booster pump station 1. Blast damage to building and equipment, 7,100 feet from GZ.

PHOTO 125–XIII. Booster pump station 2. Blast damage to building and equipment, 5,900 feet from GZ.

PHOTO 126–XIII. Bridge 29 carrying water main, damaged by blast, 1,200 feet from GZ.

PHOTO 127–XIII. Section of 16-inch water main at Bridge 29, 1,200 feet from GZ.

PHOTO 128-XIII. West abutment of Bridge 30A showing minor damage, 1,900 feet from GZ.

PHOTO 129-XIII. Blast-damaged aqueduct (Bridge 30A) carrying 16-inch water main, 1,900 feet from GZ.

PHOTO 130–XIII. Bridge 43 rebuilt, October 1945. Original bridge carrying 14-inch water main, structurally damaged by blast and fire, 5,200 feet from GZ.

PHOTO 131–XIII. Flood damage to Bridge 3 carrying 16-inch main, 7,100 feet from GZ.

PHOTO 132–XIII. Flood damage to Bridge 10 carrying 20-inch main, 7,000 feet from GZ.

PHOTO 133–XIII. Flood damage to Bridge 31 carrying 16-inch main, 4,500 feet from GZ.

c. Surface Drainage. The sewer mains also served as storm sewers to carry off a rainfall of 2.36 inches per hour. The recorded maximum was 7.87 inches per hour. Drainage water flowed through mains and open flumes (Fig. 45). The water level in the rivers often reached to within 1 foot of the tops of the revetments during flood stages.

d. Pumping System. Pumping stations (Fig. 45) were used to pump water from the open ditches to the bay areas when gates could not be opened to permit gravity flow because of high tides. Electric motors and manufactured-gas-driven engines were used as power units for the pumps, the manufactured gas being produced at each station. Since the gates at each station, which permitted gravity flow of water when opened or pumping operations when closed, were manually operated, a station attendant was required in each case to operate equipment and gates to keep the rising waters under control. Buildings housing the equipment were of the light-frame type, and are clasified on Table 35.

e. Pipe Lines. Because of the absence of human excrement, concrete pipe and open flumes were used extensively. Standard-type manholes were constructed at important intersections and where changes in direction occurred. The flow-line depth in both cases was a maximum of approximately 10 feet below ground elevation. The sewer system was composed of 211,230 linear feet of open flumes of various sizes, 3,170 feet of 48-inch-diameter clay pipe, 5,970 feet of 48- and 30-inch-diameter concrete pipe, and 74,980 feet of concrete-box pipe of varying sizes. Figure 46 shows all types of mains and flumes.

f. Damage. Of the 14 pumping stations, the equipment in six stations within a 5,200-foot radius of GZ was heavily damaged by blast and subsequent fires. The electric motors in Stations 1 and 5, however, were burned out as a result of debris falling into them while in operation. These stations were damaged by blast. The remaining stations received slight or no damage from the attack. The electric substations supplying power to the pumping stations were also damaged and could supply no electricity. Two of the buildings were structurally damaged by blast and five by fire. One building received superficial damage by blast and the remaining buildings were damaged to a minor degree. Table 35 shows the extent and nature of the damage. Since the loss of the system was not too greatly felt at the time because of the fair weather and low water, little or no effort was made to repair the damage to the stations, despite the fact that it was not heavy. The seasonal rains later caused floods which inundated the revetted areas of Hiroshima and raised the water table from its usual level to within 3 feet of ground elevation. This caused serious delay in repairing other utilities which utilized subsurface systems and manholes. All buildings in this report, including installations and equipment, are classified similarly to those in Table 35 by the Building Damage Section, and mean areas of effectiveness derived by that section for buildings and equipment will apply also for this section.

g. No damage to mains or flumes was wound by either the city engineer of Hiroshima or by members of this team.

h. Costs of Damage. The city engineers estimated the cost of damage to the sanitary and storm sewer system as of 15 November 1945 to be approximately 3,000,000 yen, or $750,000 at the exchange rate of 4 yen to a dollar.

2. Description of System

a. The city of Hiroshima was built upon the delta of six rivers which branched from the Ota River in the northern section of the city. These rivers simplified the disposal of waste water by permitting the use of short laterals leading to them. Since no raw sewage containing human excreta was discharged into the sewer system, the problem of disposal was confined to surface drainage and residential waste water. The system of short laterals accommodated 80 percent of the residences of Hiroshima, while flow from the remaining 20 percent was carried through branch pipes to the mains. Mains, open flumes, and sewage pumping stations distributed throughout the city and adjacent areas are shown on Figure 45.

b. Because of the lack of artificially produced or natural fertilizers, it was the custom throughout Japan to collect all human excrement for that purpose. In Hiroshima a regular collection system provided the necessary fertilizers for the agricultural districts. Approximately 70 percent of the collection was performed on a contract basis, contracts being let to individuals for the period of 1 year. To facilitate water transportation to the nearby islands which absorbed the total collections, a storage point was established at a wharf near Bridge 17, where excrement was allowed to ferment in tanks for approximately 30 days before

it was sold. Costs were based on a 72-liter measure and all payments by farmers and residents were made to the city government. The average monthly collection was approximately 130,000 liters. Inasmuch as the remaining 30 percent of the city zoned for collections was on the outskirts, the farmers in the vicinity of Hiroshima made their own collections and were paid the established collection rate of 30 sen per 72 liters.

c. The heaviest rainfalls occurred during the typhoon season from June through October, the highest recorded being 7.87 inches per hour on 17 September 1945. The rainfall for which provision was made in design however, was approximately 2.36 inches per hour. The system was built to accommodate as an additional load the residential waste water referred to in Paragraph 2*a*, all mains and open flumes serving the dual purpose of sanitary and storm sewers. The water impounded by open flumes and catch basins flowed through mains and open flumes, as indicated on Figures 45 and 46, directly into the rivers or the bays from high points located approximately on the longitudinal center lines of the islands formed by the rivers. In the event high river waters resulted from rains or tides, pumping stations located at strategic points (Fig. 45) discharged waters into rivers or the bay.

d. The pumping stations were made necessary by the flood stages of the rivers which frequently rose to within 1 foot of the tops of the revetments along the river banks (Photo 147) and occasionally overflowed some portions of the banks through a combination of flood and tide. This overflow, however, was rarely sufficient to cause damage.

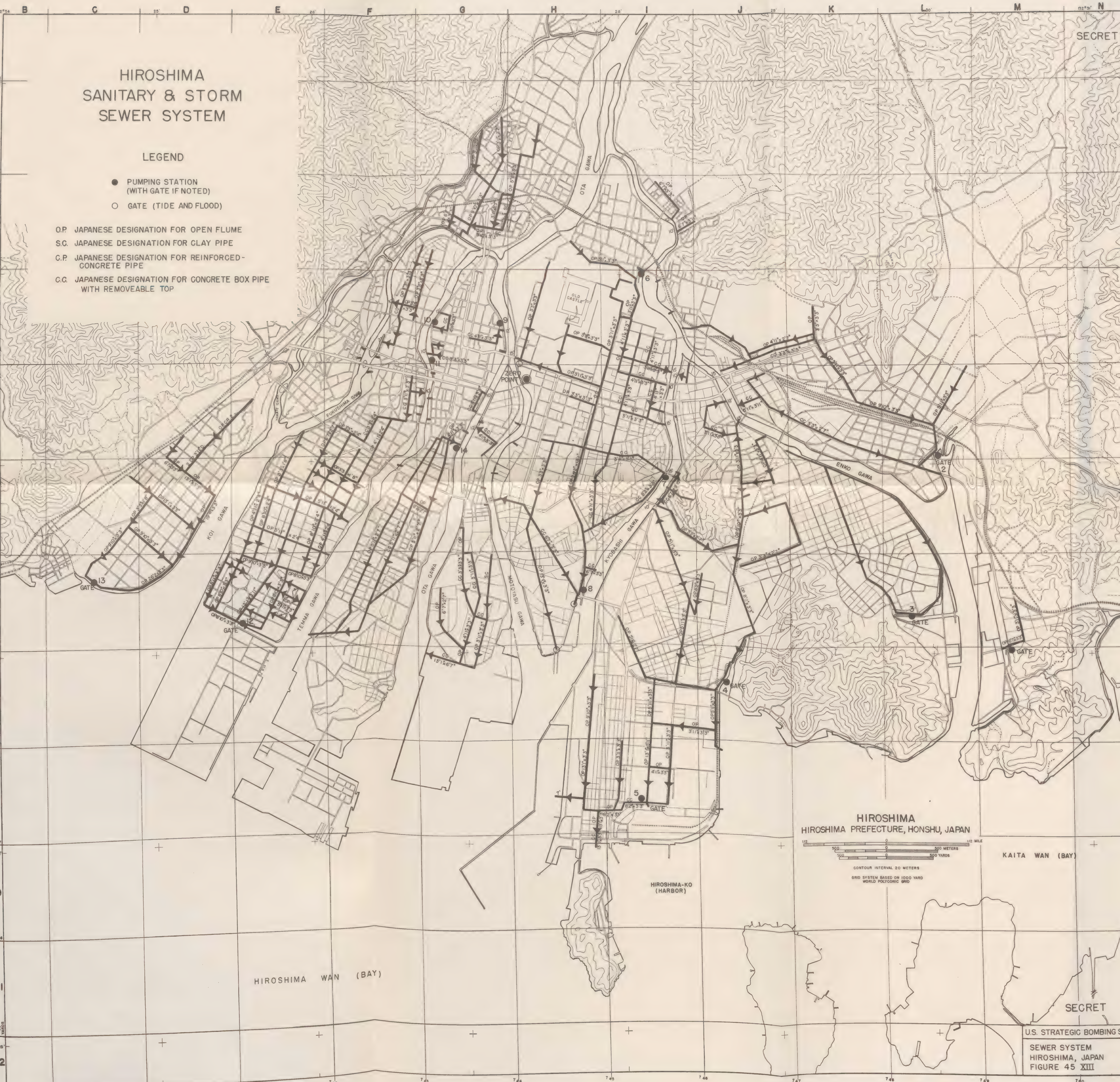
e. The sewage pumping stations were divided into two types: Those operated by electric power, and those operated by producer fuel. The power for the electrically operated stations was supplied to the city of Hiroshima by the Chugoku Electric Co. (a subsidiary of the Nippon Electric Co.), and was transformed from 3,300 volts down to operating voltages. The stations operated by producer gas generated the fuel at each individual station by heating coal or wood in air-tight containers to temperatures required to drive off the gas. The engines were 2- and 4-cycle, magneto-ignited, horizontal type, manufactured by the Osaka Co., Osaka. The location (Fig. 45), type and output of each station are listed on Table 33.

f. A total of 930 cubic feet per second was discharged by the above stations operating under normal conditions. Each station that was provided with a tide gate (Fig. 45) operated when the tide or river was too high to permit direct flow to open water. The remaining stations were provided with flood gates and pumps at sewer-main terminals from which the water was pumped when the tide water or flood water had risen too high for normal flow to the river. Other gates, in addition to those at the stations, were provided to prevent backflow during high water. All gates, either tide or flood, were manually operated and each station had its individual operator to keep the rise of waters in the mains and open flumes under control. With the exception of the pumps at Stations 15, 12, and 13 (deep-well type, manufactured by Hitachi Co., Tokyo), all pumps were of the rotary-centrifugal type, manufactured by the Torishima Pump Co., Osaka, and could operate against a maximum head of approximately 12 feet. The majority of the electric-motor-driven pumps were direct connected, while the gas-fuel-engine-operated pumps were belt driven. All stations were housed in light-frame buildings, the majority of which had interior plastered walls, but the others had exposed studding. Lighting fixtures were provided for some fuel-gas-operated stations. Table 34 gives the classifications of all buildings.

Table 33.—*Pumping stations*

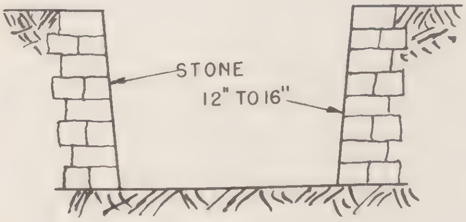
Station No.	Type	Grid No.	Horsepower, each motor	Number of pumps	Total discharge (cubic feet per second)
1	Electric motor	7M	30	1	10
2	Gas-fuel engine	5L	60	2	90
3	do	7L	30	3	30
4	do	8J	60	3	90
5	Electric motor	9I	150	3	180
6	do	4I	60	1	24
7	do	6I	60	1	24
8	Gas-fuel engine	7H	100	3	150
9	do	4G	30	2	20
10	Electric motor	4G	60	1	24
11	do	4G	60	1	24
12	do	7D	100	3	120
13	do	7C	100	3	120
14	do	5G	60	1	24

g. *Pipe Lines*. The practice of carrying all waste water and storm water by a single line greatly simplified the piping system. Because of the absence of excreta it was unnecessary to provide special construction and materials in the mains and branches to prevent early decay of sewage lines or the escape of excess sewer gas. The



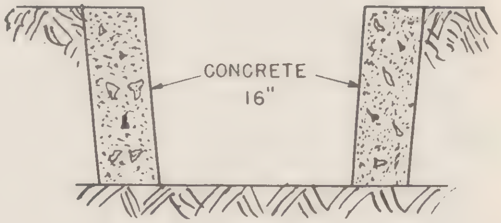
SECRET
HIROSHIMA
SANITARY & STORM
SEWER SYSTEM
LEGEND
PUMPING STATION (WITH GATE IF NOTED)
GATE (TIDE AND FLOOD)
O.P. JAPANESE DESIGNATION FOR OPEN FLUME
S.C. JAPANESE DESIGNATION FOR CLAY PIPE
C.P. JAPANESE DESIGNATION FOR REINFORCED-CONCRETE PIPE
C.C. JAPANESE DESIGNATION FOR CONCRETE BOX PIPE WITH REMOVEABLE TOP
OTA GAWA
OLD CASTLE
ZERO POINT
FUKUSHIMA GAWA
KOI GAWA
TEMMA GAWA
MOTOYASU GAWA
KYOBASHI GAWA
ENKO GAWA
GATE
HIROSHIMA
HIROSHIMA PREFECTURE, HONSHU, JAPAN
CONTOUR INTERVAL 20 METERS
GRID SYSTEM BASED ON 1000 YARD WORLD POLYCONIC GRID
KAITA WAN (BAY)
HIROSHIMA-KO (HARBOR)
HIROSHIMA WAN (BAY)
SECRET
U.S. STRATEGIC BOMBING SURVEY
SEWER SYSTEM
HIROSHIMA, JAPAN
FIGURE 45 XIII

SECRET



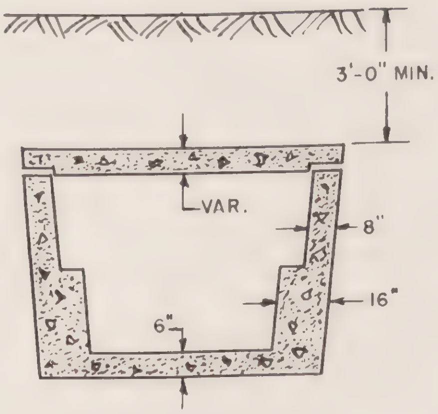
TYPICAL SECTION

STONE
OPEN FLUME



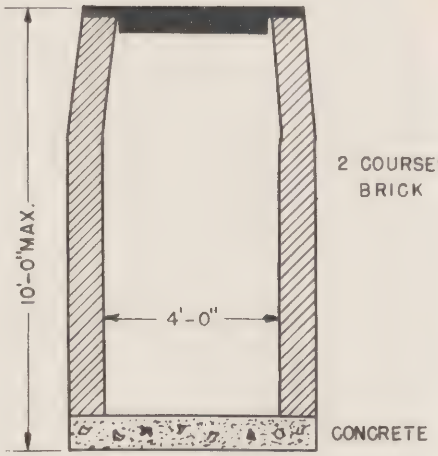
TYPICAL SECTION

CONCRETE
OPEN FLUME



TYPICAL SECTION

REINFORCED-CONCRETE
BOX PIPE



STANDARD BRICK
MANHOLE

NOT TO SCALE

SECRET

U.S. STRATEGIC BOMBING SURVEY

SEWER DETAILS
HIROSHIMA, JAPAN
FIGURE 46 XIII

PHOTO 134–XIII. Aerial photo showing open ditches and dikes at Sewer Pump Station 4, 11,100 feet from GZ.

TABLE 34-XIII.—*Hiroshima sanitary and storm sewer system—building data*

[Areas in thousands of square feet]

Building	Grid	Usage	Type	Plan area	Stories	Building HE-V	Building Fire V	Distance AZ (feet)	Total floor area	Building damage (floor area): Structural damage: Blast	Structural damage: Fire	Structural damage: Mixed	Superficial damage: Blast	Superficial damage: Fire	Minor damage	Equipment damage: Percent	Equipment damage: Cause
1	7M	Pump station	D	0.2	1	V4	C	17,000	0.2						Slight	25	Debris.
2	5L	do	D	1.2	1	V4	C	13,300	1.2	1.2						10	Do.
3	7L	do	D	1.2	1	V4	C	14,100	1.2						Moderate		
4	8J	do	D	1.2	1	V4	C	11,300	1.2						do	5	Do.
5	9I	do	D	1.1	1	V4	C	13,400	1.1						do	25	Do.
6	4I	do	D	.3	1	V4	C	5,400	.3		0.3					75	Fire.
7	6I	do	D	.3	1	V4	C	5,600	.3		.3					75	Do.
8	7H	do	D	.9	1	V4	C	7,200	.9				0.9			10	Debris.
9	4G	do	D	.4	1	V4	C	2,600	.4		.4					75	Fire.
10	4G	do	D	.4	1	V4	C	3,900	.4		.4					75	Do.
11	4G	do	D	.8	1	V4	C	3,700	.8	.8						45	Blast.
12	7D	do	D	.8	1	V4	C	11,800	.8						Severe	10	Blast and debris.
13	7C	do	D	.8	1	V4	C	14,900	.8						Slight	5	Blast.
14	5G	do	D	.3	1	V4	C	3,300	.3		.3					75	Fire.

TABLE 35.—*Flumes and mains*

Diameter or width (feet)	Open flume length OP [1]	Clay pipe length SC [2] (feet)	Concrete pipe length CP [3] (feet)	Concrete-box pipe length CC [4] (feet)
26.33	10,900			
19.75	1,100			
13.25	21,460			
11.25	800			
10.00	16,270			
9.00	9,000			
8.25	6,030			4,670
6.50	6,000			5,830
6.00	48,000			7,940
5.00	27,830			26,070
4.00	33,270	3,170	5,330	15,770
3.33	30,570			14,130
2.50			1,640	470

Depths, being variable, are not given and will be found on fig. 45.

[1] OP—Japanese designation for open flume.

[2] SC—Japanese designation for clay pipe.

[3] CP—Japanese designation for reinforced-concrete pipe.

[4] CC—Japanese designation for reinforced-concrete-box pipe with removable top.

Pipe diameters and wall thicknesses for clay and reinforced-concrete pipe were given as follows:

(1) Clay pipe, bell, and spigot, 2-inch wall, 48-inch diameter.

(2) Concrete pipe, reinforced, bell, and spigot, 2-inch wall, 48-inch and 30-inch diameter.

Fig. 46, gives open-flume and reinforced-concrete-box pipe dimensions.

minimum earth cover for all pipe was 3 feet. The types of mains and open flumes (Fig. 45) are detailed on Figure 46. The summary of types of mains and open flumes is shown in Table 35.

h. Access to Pipe. Manholes were installed at important intersections and at changes in direction. All manholes (Fig. 46) were constructed of a 2-course brick wall and a concrete foundation. The flow-line elevation, being dependent on the mean-low-water level of the river, rarely exceeded 10 feet below ground elevation.

i. All lines and mains were traced by the city engineer's office by field check and memory due to the destruction of records in the city hall.

3. Analysis of Damage

a. The greatest amount of damage to building and contents in any pumping station was caused by fire. The damage to the equipment incurred by blast was in most instances negligible. With the exception of Station 11, all stations within a radius of 5,200 feet of ground zero were destroyed by fire. Station 11 and the remaining pumping stations were damaged by blast in a degree proportionate to their distance from GZ. Table 36 cites the damage to equipment resulting from blast and subsequent fires.

b. It will be noted that the electric-motor damage of Stations 1 (Photo 135) and 5 is classified as heavy, the cause being that plaster and debris fell in the motor rotors while in operation, resulting in a severe short circuit and burning of the coils. Stations 12 (Photo 136) and 13, damaged by blast, suffered small-panel and incidental-equipment damage, insufficient to prevent operations. Since Station 12 was under construction and all equipment was not installed, however, it was not considered as being in operative condition. The equipment in the four electrically operated stations (6, 7, 10, and 14) which were damaged by fire (Photos 137, 138, and 139) was rendered totally useless as was that in gas-fuel-operated Station 9 (Photo 140). The operational value of the pumps in the fire-damaged stations was rendered negli-

TABLE 36.—*Damage to pumping station and equipment*

Station	Grid	Distance from GZ (feet)	Type of damage	Engines motors	Pumps	Distribution panels	Transformers
1	7M	16, 900	Blast	Heavy damage	None	None	None.
2	5L	13, 200	do	Slight damage	do	do	Do.
3	7L	14, 000	do	None	do		
4	8J	11, 100	do	do	do		
5	9I	13, 300	do	Heavy damage	do	None	Do.
6	4I	5, 000	Fire	do	Heavy damage	Total damage	Heavy damage.
7	6I	5, 200	do	do	do	do	Do.
8	7H	6, 900	Blast	Slight damage	None	None	
9	4G	1, 900	Fire	Heavy damage	Heavy damage		
10	4G	3, 300	do	do	do	Total damage	Do.
11	4G	3, 100	Blast	Slight damage	Slight damage	Slight damage	None.
12	7D	11, 600	do	None	None	do	Do.
13	7C	14, 800	do	do	do	do	Do.
14	5G	2, 800	Fire	Heavy damage	Heavy damage	Total damage	Heavy damage.

gible becaused of burned packing, fused bearings, and distorted shafting. As expressed above, the greatest damage incurred was by the fires as an indirect effect of the atomic-bomb explosion. With the exception of Station 11 (Photo 141) in which the electric panel and transformers were severely damaged by blast, all other stations suffered relatively light blast damage (Photos 142, 143, and 144), except stations 1 (Photo 135) and 5 which were previously discussed. Station 11 (Photo 141), although in a fire area, was an isolated case, being in a sparsely settled district.

c. Operation after the Attack. Gates controlling the gravity flow of water to the rivers or bay areas were undamaged (Photo 145) and, outside of being somewhat weathered, were considered operative. Prior to the attack there was little precipitation and only the pumping stations at the far ends of the deltas were operating to keep drainage waters in the open flumes at a safe level during high-tide periods. Subsequent to the attack, however, none of the pumping stations were operative because of (1) damages to the equipment in the pumping stations; (2) lack of competent operators, repair personnel and facilities; and (3) lack of electric power to operate electric motors in pumping stations because of damaged electric substations. Since the weather was fair at that time there was no danger of inundation, and equipment repairs could have been made in a few hours to those stations which had suffered only minor damage and were outside of a radius of 5,200 feet from GZ. Only small amounts of material would have been required for that purpose. Although the electric substations in the vicinity of these pumping stations were in operation prior to 20 August 1945, little or no effort was expended in making repairs or placing the sewer system in operation.

d. In addition to direct and indirect bomb damage, exposure to the elements contributed to the deterioration of otherwise operative equipment. During the September 1945 heavy rains which reached an all-time record high of 7.87 inches per hour, the loss of the system was greatly felt. The high water in the rivers forming the deltas prevented the escape of surface waters flowing through the mains, while the gates at the terminals of the open flumes could be opened only when the water was low. Thus at high tide the lowlands behind the revetments were inundated, the water rising to approximately 1 foot below the top of the gates. The run-off in the city center was greatly hampered. To make the problem more complex, the water table rose to within approximately 3 feet of ground elevation in the normally dry manholes of other utilities (Part D of this section), thereby greatly handicapping repair efforts. This condition was made worse by the fact that the subsurface area was reclaimed river sand and very porous.

e. Of the 14 frame structures erected to house the pumping equipment, five were damaged by fires (Photos 137, 139, and 140) and 9 were damaged by blast (Photos 141, 146, 147, 148, and 149). Table 35 gives the extent of damage to all pump station buildings. The wood-frame type structures constructed for the pumping stations were typical Japanese construction and could be readily replaced if damaged.

PHOTO 135–XIII. Equipment for Sewer Pumping Station 1. Motor damaged by debris, 16,900 feet from GZ.

PHOTO 136–XIII. Damaged equipment in sewer pumping station which was 11,600 feet from GZ.

PHOTO 137–XIII. Fire Damage to Sewer Pumping Station 7, located 5,200 feet from GZ.

PHOTO 138–XIII. Pump outlet and gravity flow outlet at Sewer Pumping Station 7, located 5,200 feet from GZ.

PHOTO 139–XIII. Fire damage to Sewer Pumping Station 14, situated 2,800 feet from GZ.

PHOTO 140–XIII. Fire damage to Sewer Pumping Station 9, situated 1,900 feet from GZ.

PHOTO 141–XIII. Blast damage to Sewer Pumping Station 11, located 3,100 feet from GZ.

PHOTO 142–XIII. Blast damage to Sewer Pumping Station 8, located 6,900 feet from GZ.

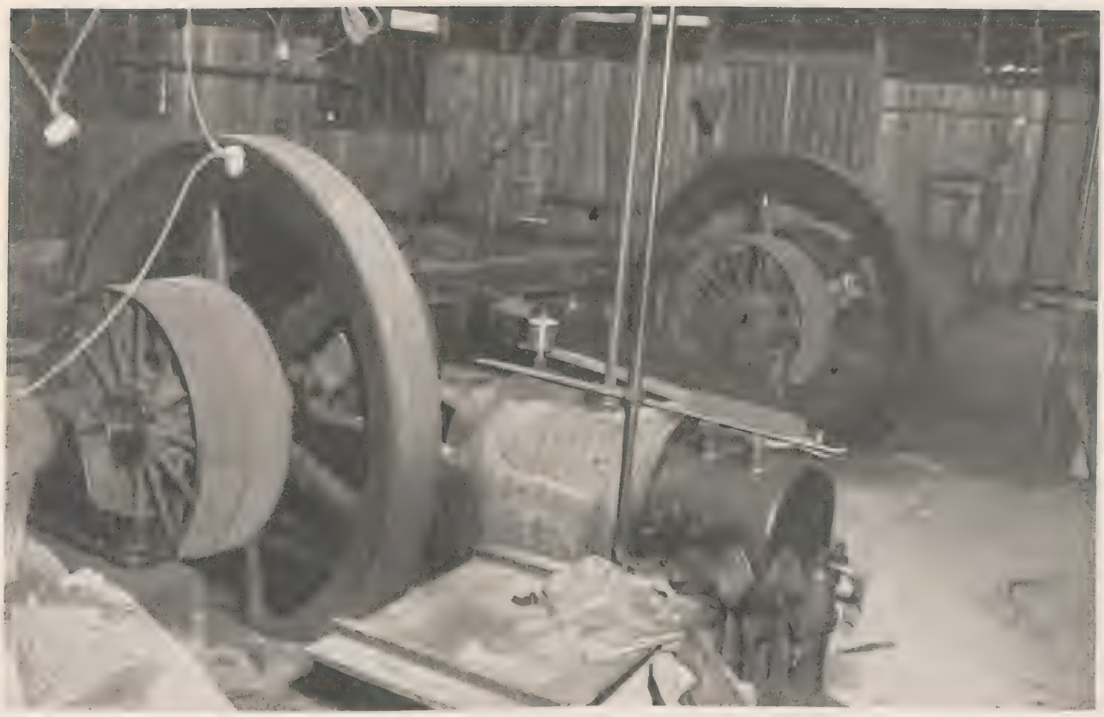


PHOTO 143–XIII. Undamaged equipment in Sewer Pumping Station 3, situated 14,000 feet from GZ.

PHOTO 144–XIII. Equipment in Sewer Pumping Station 4, situated 11,100 feet from GZ.

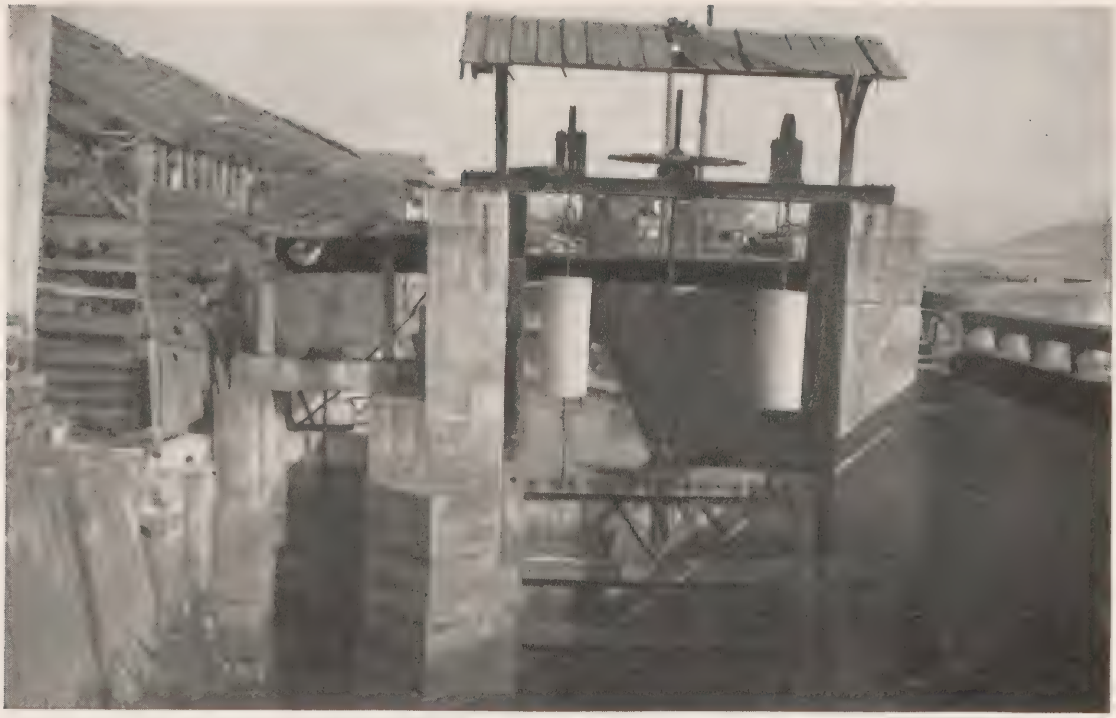


PHOTO 145–XIII. Undamaged gate at Sewer Pumping Station 8.

PHOTO 146–XIII. Sewer Pumping Station 1 showing minor blast damage.

f. There was no evidence of direct bomb damage to sewer mains (Photo 150), although the nearest reinforced-concrete-box main, 4.5 feet by 3.3 feet with a 3-foot earth cover, was only 2,100 feet from GZ. The city engineer stated that up to 15 November 1945 no breaks had been discovered. The open flumes (Photo 151) and ditches (Photo 152) were not damaged but were in some instances partly filled with mud and rubble. Of all the manholes observed not one was overflowing, a condition which would have indicated the presence of broken or crushed mains.

g. The city engineers at Hiroshima estimated the total cost of damage to the sanitary and storm sewer system at approximately 3,000,000 yen as of 15 November 1945, or $750,000 at the exchange ratio of 4 yen to a dollar.

4. Recommendations and Conclusions

a. Because Hiroshima was built upon a delta of artificially reclaimed land, separated into islands by the fast-rising rivers branching from the Ota River, it was necessary to supplement the natural run-off by a system of pumping stations to accommodate the 2.36-inch-per-hour rainfall. Prior to the atomic-bomb attack the sanitary and storm sewer system, of which the pumping stations were a part, had been adequate, since the system had always remained operative. Damage to plants and equipment, principally pumping stations, resulting from the 6 August 1945 attack, reduced the capacity of the system below the requirements of the heavy rainfall of 17 September 1945. Any city such as Hiroshima built on delta land and maintaining revetments which require the use of pumping stations for storm water and sewage disposal would be flooded by an atomic-bomb attack unless proper protection for pumping stations and mains were incorporated in its planning and construction.

b. The majority of the pumping stations were well designed and maintained, but were not all adequately electrified. Since, however, this attack damaged equipment heavily within a radius of 5,200 feet from GZ, improved electrification probably would not have altered the results in this area and stand-by units would have served no useful purpose. Outside this area, the pumping equipment, in general, withstood the attack.

c. There was no damage to the concrete or clay pipes, which indicated that the mains were of sufficient strength. Open flumes were also undamaged. Penetrating bombs could undoubtedly damage some portions of subsurface mains, but this would depend on the penetration depth, the natural slope, and type of cover. Open flumes, however, would be extremely difficult to put out of service.

d. Buildings housing the equipment were flimsy and none too well constructed. If the buildings had been constructed of reinforced concrete, much of the equipment damage resulting from the attack would not have occurred. The best method of construction for protection against an attack of this nature would be the subsurface-vault type which would have protected against both direct blast and fire damage. With equipment housed in such structures the resumption of operations would be largely dependent upon the availability of power.

G. DOMESTIC GAS SYSTEM

1. Summary

a. Production. Approximately 75 percent of the residences in Hiroshima used 1,125,000 cubic feet of producer gas per day. The heat content was maintained at 404 B. t. u. per cubic foot of gas.

b. Equipment. The producer plant was designed by the Japanese and laid out as shown on Figure 48. Equipment installed was of domestic and foreign manufacture. The high-pressure system was developed by pumping from storage into the mains. Gas was introduced into the low-pressure system from storage through a station regulator.

c. Piping. High-pressure mains were cast-iron, screwed pipe, and low-pressure mains were cast-iron, bell and spigot, lead-caulked pipes. Pressures of 6 to 8 pounds per square inch were maintained in the high-pressure mains and 6 to 8 inches of water in the low-pressure mains. All piping was buried 4 feet below ground elevation.

d. Valves. Valves were sparsely used throughout the system. Pressure reducers were valved between high- and low-pressure mains, and the mains were valved at the producer plants.

e. Bridge Crossings. There were 27 bridge crossings necessary to carry the mains across the rivers to the various islands.

f. Pressure Regulators. Pressure regulators were used to reduce pressure from 6 to 8 pounds per square inch in the high-pressure mains and to 6 to 8 inches of water in the low-pressure mains. Gas was introduced into the low-pressure mains at this point to restore pressure losses caused by friction and consumer loss.

PHOTO 147–XIII. Blast damage to Sewer Pumping Station 3, located 14,000 feet from GZ.

PHOTO 148–XIII. Blast damage to Sewer Pumping Station 12, located 11,600 feet from GZ.

PHOTO 149–XIII. Blast damage to Sewer Pumping Station 4, located 11,100 feet from GZ.

PHOTO 150–XIII. Pump outlet and gravity flow outlet at Sewer Pumping Station 6, located 5,000 feet from GZ.

PHOTO 151–XIII. Typical masonry open-flume and concrete road crossing, 7,200 feet from GZ.

PHOTO 152–XIII. Rubble-and-debris-filled concrete drainage ditch, 1,200 feet from GZ.

g. Damage to Equipment and Buildings. Total equipment damage by blast was slight. The electrical switchboard and recording meters were heavily damaged, but no other equipment was damaged. Gas storage was damaged when the crowns of the holders were torn by the direct effect of the blast, releasing all the gas which ignited. The fires that followed burned timber structures but no additional equipment damage was sustained. The electrical substation supplying this area was also damaged. The buildings (Fig. 48) in this section are tabulated as Building 112 by the Building Damage Section. Any conclusions drawn for the mean areas of effectiveness by the Building Damage Section for buildings and equipment will also apply to this Section.

h. Damage to Piping and Overcrossings. There was no apparent damage to the high- or low-pressure mains. Damage occurred to branches leading to buildings or dwellings where those structures were damaged. Of the 27 bridges serving as river crossings, four were damaged by blast and fire, and eight by floods. The extent and nature of this damage are found in Table 41. The bridges in this section are listed by number in the Bridge Damage Section and any conclusions for mean areas of effectiveness for bridges drawn by the Bridge Damage Section will also apply to this section.

i. Damage to Pressure Regulators. Of the pressure regulators installed in the system, two were heavily damaged by blast and fire, the greatest distance from GZ being 1,700 feet. This does not establish the limit of effectiveness, since the low-pressure mains served by the reducers would be affected in a degree proportionate to the damage to the reducers.

j. Cost of Damage. The estimated cost of repair and replacement was 300,000 yen, or $75,000 at the exchange rate of 4 yen to a dollar.

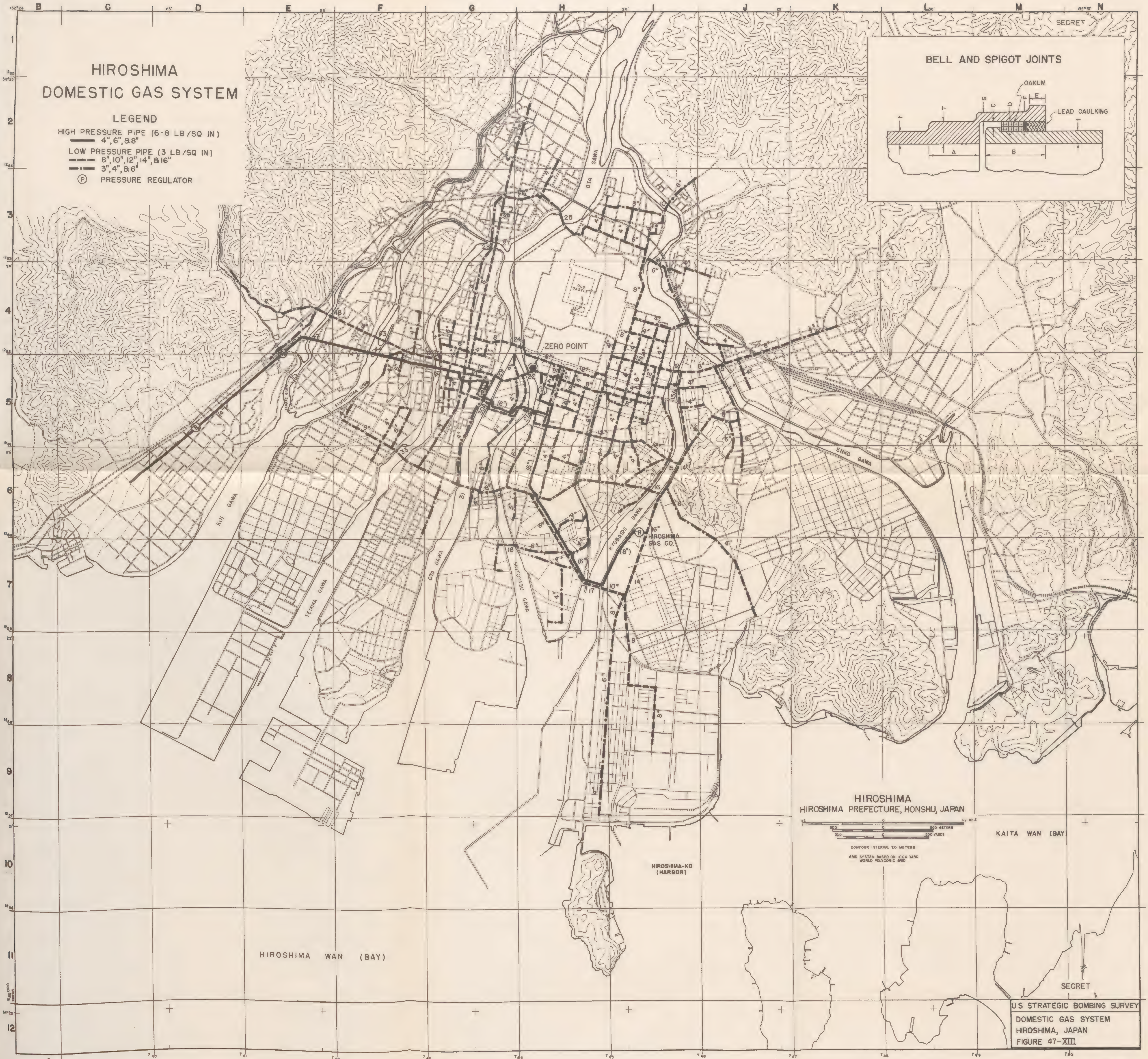
2. Description of System

a. The location of the producer plant and its connecting high- and low-pressure mains which supplied the city of Hiroshima and its environs are shown on Figure 47.

b. The producer gas was manufactured from hard coal, the bulk of it being shipped by rail to Hiroshima from the Chugoku district where Ube was a distribution point. Approximately 75 percent of the residences used gas for cooking and, in some instances, for heating. There was no industrial use of gas, coal being the main fuel for heat and power, but coke produced as a byproduct was used both by industrial plants and residences. The maximum capacity of the gas producer plant was approximately 1,125,000 cubic feet per 8-hour day, storage being in 2 holders having capacities of 316,000 cubic feet and 211,000 cubic feet, respectively. The heat content of the gas produced was maintained at 404 B. t. u. per cubic foot. The distribution system was divided into high- and low-pressure mains which carried the gas into and across the city, and also to the small district of Koi where the system ended. All pressure reductions were effected by means of pressure reducers. The fuel was then transferred through low-pressure mains to consumers.

c. The producer plant of the Hiroshima Gas Co., as indicated by Figure 48, covered approximately 2.7 acres, and included all buildings and equipment necessary for the production of domestic gas. The buildings within the plant area are covered in the Building Damage Section and are designated as Building 112 in that section. The plant was of Japanese design, but had both domestic- and foreign-equipment installations. All piping within the plant was of cast-iron, screwed pipe with flange and bolt connections. The gas holders, as indicated on Figure 49, were of the two-lift type, capable of withstanding 8 inches of water pressure. The crown of each holder was constructed in pie-shaped segments, without subcrown bracing. Rolled I-beams and framing acted as guides for rollers on each holder to keep the lifts in position. Adjustable rollers maintained free vertical movement of lifts. All joints on the holders were lapped and riveted. As shown on Figure 48, both high- and low-pressure systems started from the producer plant. In the high-pressure system gas was taken from the holders at 8 inches of water and pumped into the mains at a pressure of 6 to 8 pounds per square inch. Gas was introduced into the low-pressure mains from the holders through a station regulator of the Elester type (Fig. 50) maintaining a pressure of 6 to 8 inches of water. All gas taken from the holders was measured by flow meters before being fed into the mains.

d. The high-pressure mains were cast-iron, screwed pipe and low-pressure mains were cast-iron, bell and spigot pipe with lead-caulked joints. At bridge crossings screwed pipe with flange and bolt connections was used. Expansion joints were introduced at these points to allow for expansion


SECRET
HIROSHIMA
DOMESTIC GAS SYSTEM
LEGEND
HIGH PRESSURE PIPE (6-8 LB/SQ IN)
4",6",& 8"
LOW PRESSURE PIPE (3 LB/SQ IN)
8",10",12",14",& 16"
3",4",& 6"
P PRESSURE REGULATOR
BELL AND SPIGOT JOINTS
OAKUM
LEAD CAULKING
ZERO POINT
OLD CASTLE
OTA GAWA
KOI GAWA
TEMMA GAWA
MOTOYASU GAWA
KYOBASHI GAWA
ENKO GAWA
FUKUSHIMA GAWA
HIROSHIMA GAS CO.
HIROSHIMA-KO (HARBOR)
HIROSHIMA WAN (BAY)
KAITA WAN (BAY)
HIROSHIMA
HIROSHIMA PREFECTURE, HONSHU, JAPAN
CONTOUR INTERVAL 20 METERS
GRID SYSTEM BASED ON 1000 YARD WORLD POLYCONIC GRID
SECRET
US STRATEGIC BOMBING SURVEY
DOMESTIC GAS SYSTEM
HIROSHIMA, JAPAN
FIGURE 47-XIII

SECRET

U.S. STRATEGIC BOMBING SURVEY

HIROSHIMA GAS COMPANY
HIROSHIMA, JAPAN
FIGURE 48 - XIII

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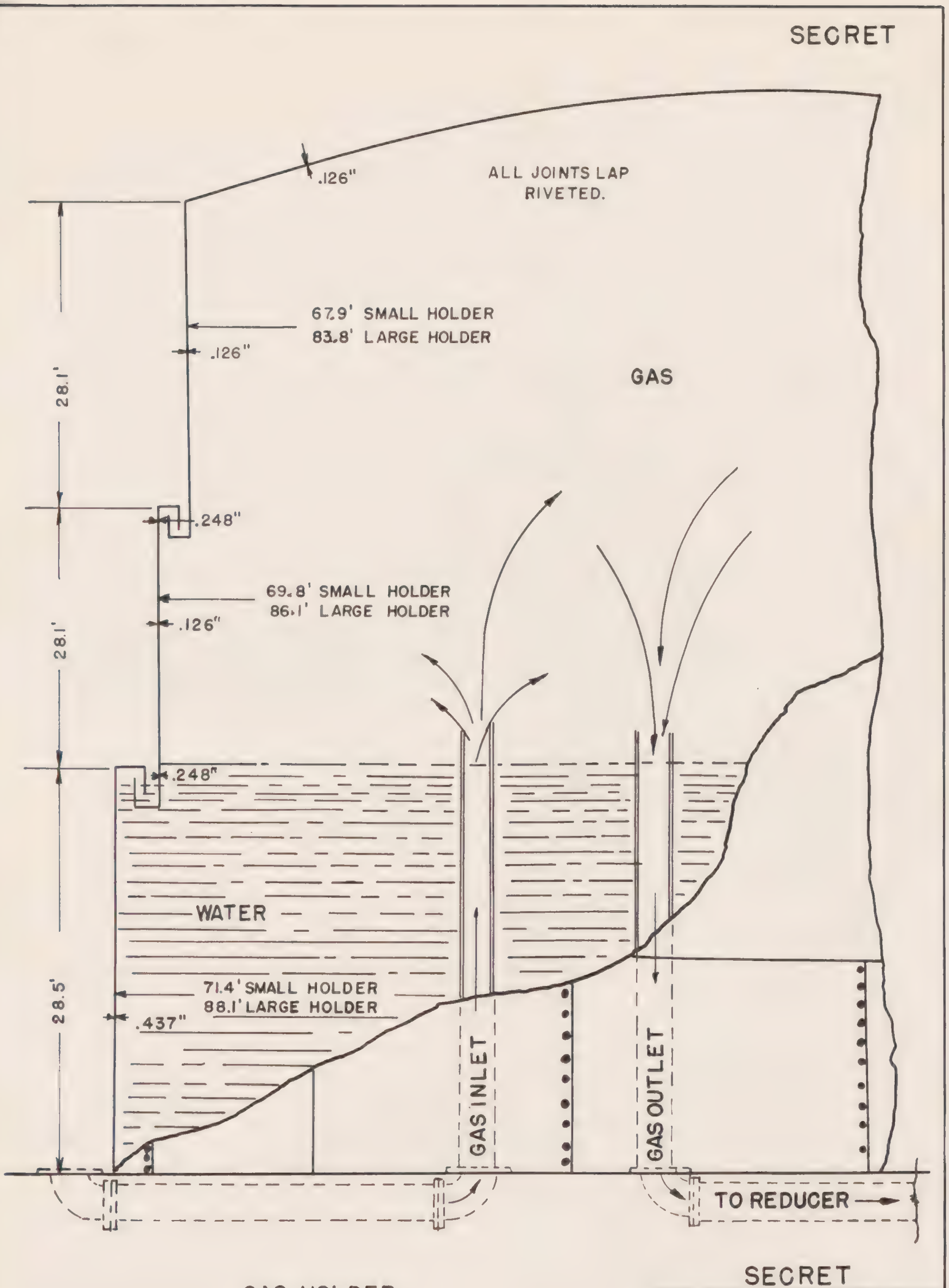

GAS HOLDER

U.S. STRATEGIC BOMBING SURVEY

HIROSHIMA GAS COMPANY
HIROSHIMA, JAPAN.
FIGURE 49 XIII

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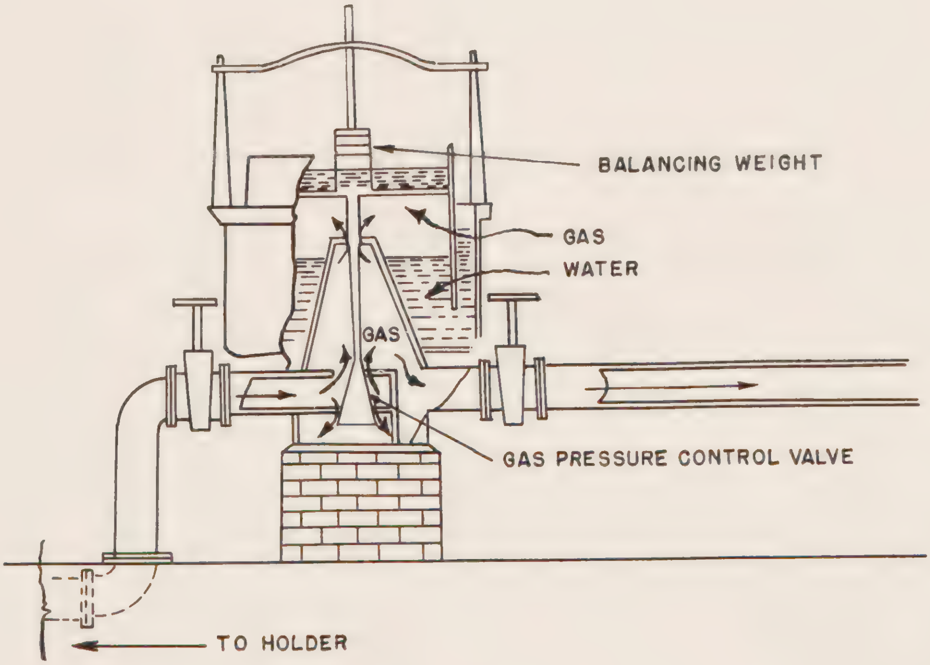

STATION GAS REGULATOR

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U.S. STRATEGIC BOMBING SURVEY
HIROSHIMA GAS COMPANY HIROSHIMA, JAPAN FIGURE 50 XIII

and contraction with changes in temperature. Table 37 gives the dimensions for bell and spigot pipe used by the company. For details see Figure 47.

TABLE 37.—*Dimensions of cast-iron, bell-and-spigot pipe*

Diameter (inches)	A	B	C	D	E	F	G	H	T	t
3	3	3	1/4	7/8	3/4	1 1/16	5/8	3/4	1/2	3/8
4	3	3	1/4	7/8	3/4	1 1/16	5/8	3/4	1/2	3/8
6	3 1/2	3 1/2	3/8	7/8	7/8	1 3/16	1 1/16	7/8	5/8	7/16
8	4	4	3/8	1 1/8	7/8	1 3/16	1 1/16	7/8	5/8	1/2
10	4	4	3/8	1 1/8	7/8	1 3/16	1 1/16	3/4	5/8	9/16
12	4	4	3/8	1 1/4	7/8	1 5/16	1 3/16	1 1/8	3/4	5/8
14	4 1/2	4 1/2	3/8	1 3/8	1 1/16	1 5/16	1 3/16	1 1/4	7/8	1 1/16
16	4 1/2	4 1/2	3/8	1 3/8	1 1/16	1 5/16	1 3/16	1 1/4	7/8	5/8

Standard length of each size of cast-iron pipe was 9 feet.

e. Very few valves were employed in either the high- or low-pressure systems. They were used only at the pressure reducers and at the producer plant where the high- and low-pressure systems were valved as a maintenance measure. The approximate depth of placement of all pipe was 4 feet below ground elevation; it emerged only at river crossings or at reducers. Table 38 is a tabulation of all high- and low-pressure pipes as indicated on Figure 47.

TABLE 38.—*High- and low-pressure piping*

Diameter (inches)	High-pressure, cast-iron, screwed pipe (feet)	Low-pressure, cast-iron, bell-spigot pipe (feet)
16		9, 900
14		1, 600
12		23, 100
10		6, 600
8	3, 300	42, 900
6	13, 200	47, 000
4	16, 500	94, 000
3	33, 000	3, 500

f. Twenty-seven bridges were used as overcrossings for domestic gas lines, only bridges owned and maintained by the city or the prefectural government being used, with the exception of Bridge 21A which was maintained by the company. Table 39 gives the bridges used as overcrossings for gas mains as shown on Figure 47.

TABLE 39.—*Gas main overcrossings*

Bridge	Grid	Type	Number of spans	Bridge length (feet)	Size of pipe (inches)	
					High pressure	Low pressure
5	5J	Concrete	5	204		8
7	4I	do	8	288		4
8	4I	do	13	518		6
10	3I	do	7	307		6
12	5I	Plate girder	3	208		8
13A	5I	Timber	9	307		12
15	6I	do	15	309		12
16	6I	Concrete	7	367		4
17	7H	Plate girder	9	540	6	10
18	7G	Timber	16	448		6
19	6G	Concrete	7	259		6
21A	5H	Timber	9	270	6	12
22	5H	Plate girder	3	164		8
24	4G–H	do	7	398		8
25	3H	Concrete	14	560		6
27	3G	Steel arch	1	200		8
28	3G	Timber	6	197		4
29	5G	Pin truss	3	263		12
30	5G	Concrete	7	340	6	12
31	6G	do	12	358		6
33	6F	do	12	410		6
35	5G	Plate girder	8	264	4	
37	5G	do	4	169		10
43	4F	Timber	16	410		8
44	4F	Steel I-beam	14	476	4	
47	4E	do	10	340	4	
48	4E	Plate girder	4	240		4

Data for the above bridges are taken from the Bridge Damage Section.

g. In order to keep the pressures in the low-pressure mains from being absorbed by friction and consumer loss, pressure regulators as shown on Figure 47 were inserted to transfer gas from the high-pressure mains. Gas at 6 to 8 pounds per square inch in the high-pressure mains was reduced to 8 inches of water for consumer distribution. This equipment was manufactured by the Reynolds Gas Regulation Co., of Anderson, Ind. (Fig. 51).

3. Analysis of Damage

a. At the time of the atomic-bomb attack of 6 August 1945, the domestic gas plant of the Hiroshima Gas Co., at a distance of 6,700 feet from GZ, was producing at its maximum capacity. Initial damage by blast to operating equipment was slight (Photo 153). The electrical distribution panel in the pumping station received heavy damage to the wiring and meters (Photo 154). The station recording meters were also heavily damaged. Replacements of parts were necessary to

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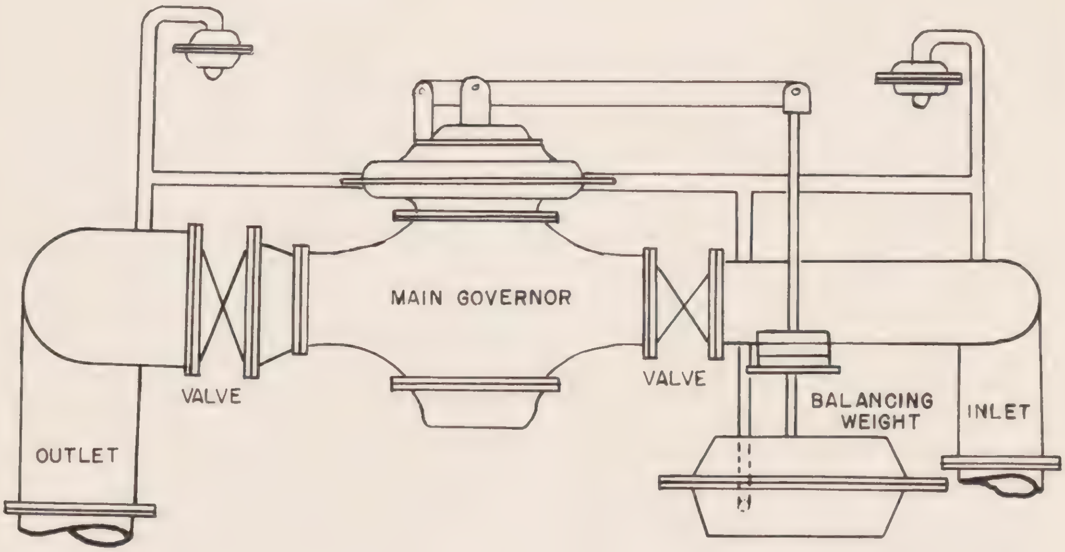


REYNOLDS GAS REGULATOR CO.
ANDERSON, IND., USA

GAS SYSTEM REGULATOR

SECRET

U.S. STRATEGIC BOMBING SURVEY
HIROSHIMA GAS COMPANY HIROSHIMA, JAPAN FIGURE 51 XIII

make this equipment operative. The gas holders, however, were more severely damaged (Photo 155). The holder crowns were depressed by the blast (Photo 156) and the downward vertical movement of the lifts compressed the gas sufficiently to build a pressure that tore the already weakened riveted joints when the pressure from the blast front was released, which allowed the gas to escape. There was an immediate ignition but no explosion, and all the escaping gas was consumed by fire. Since no gas pressure remained to hold the two lifts of each holder above the water elevations of the water receptacles, both lifts of each holder dropped to the floor elevation of the water receptacle. Framing members, however, were undamaged. All operations in the production plant stopped immediately. Three hours subsequent to the blast, fires were started in the plant area, having been driven to the vicinity by a south wind. Because of the immediate drop in water pressure and the lack of electricity to operate the auxiliary water pumps, no effort could be made to extinguish the fires. The Sendamachi electric substation in this area was damaged and electric power was interrupted. No additional damage to the equipment by fire was noted.

b. Flash burns affecting the bituminous paint on the gas holders (Photo 157) were visible on the sides of holders toward the blast. The structural members and other obstructions protecting the paint from the flash are outlined on the holders, and were easily distinguished.

c. The damage to the gas holders was insufficient to halt operations because the producing plant could operate until facilities could be repaired by pumping gas directly into the lines without the benefit of storage, and the small repairs to the collateral equipment required a minimum of time and materials, which would permit the plant to operate at its rated capacity. Company officials stated that after small equipment repairs, operations would begin early in 1946 by pumping directly into the lines. This statement did not seem unreasonable after inspection of the plant. Figure 48 shows the damage to company buildings caused by blast and fire.

d. An examination by the company indicated no breaks in the mains, but since no gas was available a pressure test was not made to test for leaks in the lead joints. Approximately 75 percent of the branches from the mains to dwellings and buildings were damaged when those structures suffered damage by blast and fire.

e. As reported by the bridge damage section of this survey a number of bridges were damaged by blast, fire (Photos *99, #130, 158, and 159) and flood (Photos *102 and 160). (Refer to Parts D and E of Sec. XIII for explanation of * and #.) Inasmuch as these bridges served as overcrossings for utilities, gas flow was rendered impossible by their damage or destruction. Since the floods of 17 September and 5 October 1945 occurred subsequent to the atomic-bomb attack, damage attributed to the floods is mentioned to give a complete history. Table 40 is a tabulation of damage to bridges serving as overcrossings for the gas distribution system (Fig. 47) as taken from the bridge damage section of this report.

f. Because of the loss of whole sections of mains, both high- and low-pressure type, due to loss of bridges, districts served by these overcrossings will continue to be cut off entirely until bypasses are made. In the event it were possible to operate the producing plant such operations would be greatly reduced because of the number of bridges damaged or destroyed as a direct or indirect result of the attack.

g. In tracing the possible bypasses (Fig. 47 and Table 41) required to operate the system, the 12-inch crossing at Bridge 13A (Photo #130) could be eliminated since 8- and 12-inch low-pressure mains on Bridges 12 and 15 in the immediate vicinity were available. However, the breaks in the 6-inch high-pressure main and the 12-inch low-pressure main at Bridge 21A (Photo 158) constituted a serious problem. The 6-inch high-pressure main over this bridge provided sufficient pressure to overcome friction losses in the low-pressure mains and bypasses within that area. The 6- and 8-inch low-pressure mains over Bridges 19, 22, and 24 might have been sufficient to provide the necessary gas required for the area west of the Motoyasu River had not the 12-inch low-pressure main on Bridge 29 (Photo 159) been also damaged. This area was cut off entirely, and unless temporary structures were erected to provide an overcrossing for at least the 6-inch high-pressure main, very little gas would be available to the area west of the Motoyasu River. The break in the 8-inch low-pressure main over Bridge 43 (Photo #130) would be negligible because there was no high-pressure supply. However, since no valves were installed in this system any attempt to bypass

PHOTO 153–XIII. Damage by blast to coking ovens at the Domestic Gas Plant, 6,700 feet from GZ.

PHOTO 154–XIII. Damage to electrical switchboard panel in Building 112, 6,700 feet from GZ.

PHOTO 155–XIII. Fire and blast damage to gas holders and buildings, 6,500 feet from GZ.

PHOTO 156–XIII. Crown of holder depressed by blast and section raised by compressed gas, 6,500 feet from GZ.

PHOTO 157–XIII. Flash burns on gas holder 6,500 feet from GZ. Note shadow of office building on holder.

TABLE 40.—*Damage to overcrossings*

Bridge	Type	Length (feet)	Distance from GZ	Size of pipe (inches) High pressure	Size of pipe (inches) Low pressure	Damage	Extent
5	Concrete	204	6, 200		8	None	
7	do	288	5, 200		4	do	
8	do	518	5, 400		6	do	
10	do	307	7, 000		6	Flood	Moderate.
12	Plate girder	208	4, 700		8	None	
13A	Timber	307	4, 700		12	Blast and fire	Complete destruction.
15	do	309	4, 700		12	None	
16	Concrete	367	5, 800		4	do	
17	Plate girder	540	7, 600	6	10	do	
18	Timber	448	6, 000		6	do	
19	Concrete	259	4, 300		6	do	
21A	Timber	270	1, 200	6	12	Blast and flood	Do.
22	Plate girder	164	260		8	None	
24	do	398	1, 000		8	Blast	Slight.
25	Concrete	560	5, 200		6	Flood	Moderate.
27	Steel arch	200	4, 400		8	None	
28	Timber	197	4, 400		4	Flood	Complete destruction.
29	Pin truss	263	1, 200		12	Blast	Do.
30	Concrete	340	1, 900	6	12	Flood	Severe.
31	do	358	4, 600		6	do	Do.
33	do	410	5, 300		6	do	Do.
35	Plate girder	264	3, 200	4		do	Complete destruction.
37	do	169	3, 200		10	do	Severe.
43	Timber	410	5, 200		8	Blast and fire	Complete destruction.
44	Steel I-beam	476	5, 300	4		None	
47	do	340	7, 500	4		do	
48	Plate girder	240	7, 100		4	do	

would necessitate the installation of valves to accommodate each bypass. The floods of 17 September and 5 October 1945 totally or heavily damaged other bridges (Photos *102 and 160) as was previously shown and presented additional difficulties since they also served as utility overcrossings.

h. Pressure regulators in the distribution system located on Figure 47 were damaged (Table 41) as follows:

TABLE 41.—*Regulator damage*

Pressure regulator	Distance from GZ (feet)	Type	Damage extent
1	700	Blast and fire	Heavy.
2	1, 700	do	Do.
3	7, 600	None	
4	10, 700	do	

The greatest damage to Regulators 1 (Photo 163) and 2 (Photo 164) was distortion to the balancing mechanism and freezing of the valves by fire. Only a small amount of damage was incurred by blast and that was by flying debris. Both regulators, however, were rendered useless. No damage was visible to Regulators 3 and 4 and no breaks or damages to piping was noted at these points of exit.

i. The estimated cost of repair and replacements of equipment and material by the company as of 15 November 1945 was 300,000 yen or $75,000 at the rate of 4 yen to a dollar.

4. Recommendations and Conclusions

a. The gas producing plant, although 6,700 feet from GZ, received sufficient equipment damage to halt production of domestic gas. The weak point in the system was the electrical distribution panel. The metering system and gas holders, not being essential to production, could be bypassed until repairs were effected. It can be concluded that a well protected electrical distribution panel would eliminate this weak point and, upon resumption of electrical power supply, the gas plant, with bypasses and few repairs would be in operation.

PHOTO 159–XIII. Broken gas main at Bridge 29. Over-crossing structurally damaged by blast, 1,200 feet from GZ.

PHOTO 160–XIII. Bridge 30, carrying 6-inch, high-pressure and 12-inch, low-pressure gas mains, damaged by flood. Aqueduct 30A in background, 1,900 feet from GZ.

PHOTO 158–XIII. Damaged gas-main supports at Bridge 21A, 1,200 feet from GZ.

PHOTO 161–XIII. Bridge 27 carrying 8-inch, low-pressure gas main, undamaged, 4,400 feet from GZ.

PHOTO 162–XIII. Undamaged Bridge 47 carrying 4-inch, high-pressure gas main, 7,500 feet from GZ.

PHOTO 163–XIII. Pressure Regulator 1 damaged by debris and fire, 800 feet from GZ.

PHOTO 164–XIII. Pressure Regulator 2 damaged by debris and fire, 1,800 feet from GZ.

b. There was no damage to the cast-iron, screwed or bell and spigot pipe buried at 4 feet below ground elevation. The damage, however, to the dwellings and buildings to which the pipes were extended, damaged the gas branches. Because of the vulnerability of the dwellings and buildings, this damage would occur regardless of locality. But an efficient cut-off system for each branch from the main would aid in maintaining main pressures and reduce the loss of gas until branches above ground were repaired.

c. Because of the islands on which Hiroshima was built, numerous bridges were necessary to keep communications open. The domestic gas mains were dependent on these bridges as overcrossings, and the failure of any bridge acting as an overcrossing might also mean the failure of part of the system. If a high-pressure main were being carried, the whole system beyond that point would be out of service. This would be true where the attack damaged bridges carrying a 12-inch low-pressure main and a 6-inch high-pressure main. The area beyond those points could not be served by low-pressure pipes because of pressure losses. But subriver crossings would eliminate these hazards and should be utilized as much as possible to minimize the damage from similar attacks.

d. Pressure regulators converted high pressure to low pressure for consumer distribution. The damage received by regulator 2 at 1,700 feet from GZ did not confine the limit of effective damage solely to its area for these reasons: (1) Damage was such that no gas could flow and the area was cut off in proportion to the distance to the next regulator, depending on a loop system being in the area, or (2) the pressure in the high- and low-pressure systems was equalized, creating a dangerous situation for consumers. In order to protect the regulators against damage from similar attacks a good solution would be to install them in reinforced-concrete manholes constructed below ground elevation.

SECTION XIV

DAMAGE TO STACKS

1. Summary

The part of Hiroshima which was affected by the blast of the atomic bomb contained numerous stacks of reinforced concrete, brick, and steel (Photos 1 to 4), averaging less than 70 feet in height and designed to serve small industries and public buildings. Very few stacks in excess of 100 feet in height had been built in this area. In obtaining data, a method of sampling was employed which gave a good cross-section of both damaged and undamaged stacks of the three most prevalent types. The survey revealed the stacks to be generally well designed, but frequently poorly constructed. Although in many instances, particularly in the case of undamaged stacks, it was impossible to get complete details and dimensions, sufficient data were obtained to lead to reasonable conclusions. It was estimated that within a concentric area of an 8,700-foot radius from GZ (beyond which no further damage to stacks was encountered) 15 percent of the concrete, 50 percent of the brick, and 70 percent of the steel stacks were damaged sufficiently to render them unusable without almost complete rebuilding. In all cases the cause of damage was believed to be blast. Detailed analysis of the data disclosed mean effective areas against stacks constructed of concrete, brick, and steel to be 0.3, 2.7, and 4.1 square miles, respectively (Fig. 1).

2. Lay-out and Construction

One of the oddities in the appearance of Hiroshima was the existence of numerous apparently undamaged stacks rising out of the rubble of the flattened buildings they had formerly served. Further elaboration of this picture is given in the succeeding subparagraphs.

a. Types of Stacks. The portion of Hiroshima which was most heavily damaged by the atomic bomb contained numerous stacks, both damaged and undamaged, averaging less than 70 feet in height. Large stacks serving heavy industry were few in number in this area; only six of those studied were 100 feet high or over, the highest being 120 feet. Concrete stacks were by far the most numerous; brick types averaged less than a third of the total; and steel units were little in evidence. Several other types, such as vitrified-tile and asbestos-pipe, were encountered but were not considered worthy of study.

b. Survey Method. The survey was based not upon data from all stacks in the area, but upon a sampling of the area. The method employed was to compile data on stacks selected for study on the basis of location, type, and degree of damage, in order that accumulated data might represent a fair sampling of all the stacks. Proceeding clockwise around GZ, 16 stacks were selected from the northeast quadrant of the city, 23 from the southeast, 14 from the southwest, and 13 from the northwest. The stacks were distributed over the quadrants and extended 8,700 feet from GZ, beyond which no further damage was encountered.

c. Functions. Most of the stacks in the blast area had served small industry and public buildings. Large stacks serving heavy industry, which was not very prevalent in Hiroshima, were confined largely to the southern extremities of the several islands comprising the city and hence were beyond the effects of the atomic blast. Typical industries served by the stacks studied in this survey included relatively small establishments for the manufacture of needles, cameras, paint, matches, precision instruments, and similar items.

d. Design and Construction. Concrete stacks appeared to be well designed. Walls were sufficiently strong to withstand heavy wind-loads, as well as the earth tremors so prevalent in Japan, without any appearance of clumsiness or excessive thickness. Spacing and size of reinforcing steel, wherever exposed to view, compared favorably with United States standards. The quality of workmanship, however, was generally mediocre. Reinforcing steel was not carefully placed and concrete thickness was permitted to vary considerably. Clumsy wood forms were used in sections averaging 4 or 5 feet in height, rather than the more practical steel slip forms. Some stacks were coated with a half inch of cement plaster in an effort to cover their rough appearance. Many of the concrete stacks were brick lined, usually one course, to a height of 10 or 15 feet. Brick stacks, especially the larger, octagonal-shaped ones, were usually both well designed and well constructed. Materials and workmanship were good. The smaller, square-shaped brick stacks, such as might be used on a public bath house, were built too lightly and frequently had to be braced with angle iron or steel straps and bands. Steel stacks were in a small minority. They followed no apparent standard in design; some were lap welded; others had riveted joints. Their chief weakness lay in the method of anchoring them to the brick base; anchor bolts, for example, extended through only four

courses of brick in some instances, and were ineffective in preventing overturning.

3. Analysis of Damage

a. Tabular Data. Table 1 shows the physical characteristics of each stack studied and the extent of damage, if any.

b. Extent and Cause of Damage. It is estimated that within a radius of 8,700 feet from GZ 15 percent of the concrete, 50 percent of the brick, and 70 percent of the steel stacks were damaged sufficiently to make them unusable without almost complete rebuilding (Photos 5 to 22). The remainder suffered either no damage or only minor damage, such as loosening of the cement-plaster finish coating or loss of all or a part of the steel ladders. Minor damage which would permit reuse of the stack without repair was not considered in this report as damage. The cause of damage was believed to be blast in all instances, since there was no evidence of spalled concrete, vitrified brick, or oxidized steel which would have pointed to fire as the cause of damage.

c. Evaluation of Field Data. A total of 66 stacks was studied. It was possible to get good data on the 20 damaged stacks. On a few of the undamaged stacks it was possible to get data on thickness, size, and spacing of reinforcing steel, and other characteristics where the entrance of the breeching was above ground and accessible, but it was impossible to get complete data as the flue entrance was usually underground and covered with tons of rubble and debris. All concrete stacks, even though no reinforcing steel was visible, were believed to be reinforced. Although some data were impossible to obtain without destroying the stacks, sufficient information was secured to lead to reasonable conclusions.

4. Recommendations and Conclusions

Analysis of the data revealed reinforced-concrete stacks to be the most effective in withstanding the blast of the atomic bomb. Brick proved highly vulnerable, and steel appeared most subject to damage. The mean areas of effectiveness of the bomb against stacks of reinforced concrete, brick and steel were 0.3, 2.7, and 4.1 square miles, respectively. The mean effective radii were 1,625, 4,900, annd 6,050 feet. These conclusions, it must be remembered, are based upon the effects on stacks which averaged less than 70 feet in height. From the standpoint of economy, speed, and ease of construction it appeared that practically all of the stacks studied and reported on herein should have been constructed of steel pipe securely anchored to a reinforced-concrete base. Such a stack, even though blown down, could be quickly repaired on the ground and re-erected in one piece with the aid of a crane. Higher stacks, such as those of 100 feet or more, should be built of reinforced concrete or brick. The preponderance of concrete and brick as materials for stacks averaging no higher than those studied in Hiroshima was probably a reflection of the relative scarcity of steel and abundance of cheap labor in Japan.

Legends:
NA—Not applicable.
---—Unknown.

TABLE 1–XIV.—*Damage to Stacks*

Stack number	Grid	Distance from GZ (feet)	Type	Cross section	Height (feet)	Size: Base (feet)	Size: Top (feet)	Thickness: Base (inches)	Thickness: Top (inches)	Longitudinal reinforcing: Size (inches)	Longitudinal reinforcing: Space (inches)	Horizontal reinforcing: Size (inches)	Horizontal reinforcing: Space (inches)	Special features	Description of damage from base
1	5H	550	Concrete	Circle	70	4	2	5½	---	⅝	9	(1)	(2)	None	None.
2	5H	500	do	do	70	4	2	---	---	---	---	---	---	do	Do.
3	5H	1,100	do	do	60	4	2	5	4	½	5	¼	5	Brick lined to 10 feet	Sheared off at 12 ft.
4	5H	1,700	Brick	Hexagon	60	7	---	18	---	NA	NA	NA	NA	None	Do.
5	6H	4,100	do	Square	65	5	3	---	---	NA	NA	NA	NA	do	None.
6	6H	4,900	Concrete	Circle	75	4¼	2½	---	---	---	---	---	---	do	Do.
7	7G	6,100	Brick	Octagon	85	12	8	6	6	NA	NA	NA	NA	Steel straps and bends on top third.	Do.
8	7G	6,100	Concrete	Circle	90	9	6	---	---	---	---	---	---	None	Do.
9	6G	5,500	Steel, brick base	do	53	2½	2½	¼	¼	NA	NA	NA	NA	Brick base 4 feet high	Do.
10	6G	5,300	Concrete	do	60	4	3	---	---	---	---	---	---	None	Do.
11	4G	1,600	do	do	60	4	2½	7	---	¾	9	---	---	Brick lining	Do.
12	4G	1,900	do	do	60	4	3	6	---	½	9	⅜	---	do	Fracture at 16 ft.
13	5G	2,400	do	do	65	4	2½	7	---	¾	5	⅜	6	do	None.
14	4G	2,400	do	do	60	3½	2	5	4	⅝	5	¼	6	None	Sheared off at 15 ft.
15	4G	2,700	do	do	70	4½	3	---	---	---	---	---	---	Brick lining	None.
16	4G	3,700	do	do	70	4	2½	---	---	---	---	---	---	None	Do.
17	4G	4,000	do	do	70	4	2½	---	---	---	---	---	---	do	Do.
18	4G	4,100	Brick	Octagon	55	8	5	28	---	NA	NA	NA	NA	Steel straps and bands on top two-thirds.	Do.
19	4G	4,200	do	Square	55	6	---	13	---	NA	NA	NA	NA	None	Sheared off at 35 ft
20	4G	4,200	do	do	55	6	---	13	---	NA	NA	NA	NA	do	Do.
21	4G	4,200	Concrete	Circle	65	3½	2	---	---	---	---	---	---	do	None.
22	4G	4,400	do	do	65	3½	2	---	---	---	---	---	---	do	Do.
23	6I	6,200	Brick	Octagon	70	8	5	26	---	NA	NA	NA	NA	do	Do.
24	6I	6,300	Concrete	Circle	115	9	6	---	---	---	---	---	---	do	Do.
25	6I	6,400	do	do	95	8	5	---	---	---	---	---	---	do	Do.
26	6I	6,500	do	do	100	6	4	---	---	---	---	---	---	do	Do.
27	7I	6,800	do	do	60	4	2	---	---	½	4	¼	12	Strengthened with 11 steel bands.	Fractured at 40 feet.
28	7I	6,900	Steel, brick base	do	60	1⅔	1⅔	¼	¼	NA	NA	NA	NA	None	Steel portion knocked off of base.
29	6H	5,700	Brick	Square	50	6	3	22	---	NA	NA	NA	NA	do	None.
30	5I	5,000	do	do	50	5	---	---	---	NA	NA	NA	NA	do	Crack at 28 feet; sheared off at 35 feet.
31	5I	5,100	Concrete	Circle	75	4	2½	---	---	---	---	---	---	do	None.
32	6G	4,000	Brick	Square	40	4	2	---	---	NA	NA	NA	NA	do	Sheared off at 20 feet.
33	7F	8,700	Concrete	Circle	80	4	2	---	---	---	---	---	---	do	None.
34	7F	8,400	Brick	Octagon	70	8	4	---	---	NA	NA	NA	NA	do	Do.
35	7F	8,200	Concrete	Circle	70	4	2	6	---	½	---	---	---	do	Do.
36	7F	8,000	Brick	Octagon	65	9	5	---	---	NA	NA	NA	NA	do	Cracks above 10 feet; sheared off at 20 feet.

Stack number	Grid	Distance from GZ (feet)	Type	Cross section	Height (feet)	Size		Thickness		Longitudinal reinforcing		Horizontal reinforcing		Special features	Description of damage from base
						Base (feet)	Top (feet)	Base (inches)	Top (inches)	Size (inches)	Space (inches)	Size (inches)	Space (inches)		
37	7F	8, 100	Brick	Square	50	5½	3	13		NA	NA	NA	NA	Upper half braced with vertical and horizontal angle iron.	Cracks above 10 feet; sheared off at 30 feet.
38	6G	4, 500	do	do	60	4½	2	13	9	NA	NA	NA	NA	do	Do.
39	4H	1, 550	Concrete	Circle	100	5	3							None	None.
40	4H	2, 100	do	do	83	5	3							do	Do.
41	3H	3, 600	do	do	60	5	3							do	Do.
42	3H	3, 800	do	do	100	6	4							do	Do.
43	4H	3, 000	do	do	72	5	3	8		⅝	6			do	Do.
44	4I	4, 800	Brick	Octagon	69	5½	3½			NA	NA	NA	NA	do	Do.
45	4I	4, 200	Concrete	Circle	115	7	5							do	Do.
46				None											
47	5H	1, 700	Concrete	Circle	70	5	3							None	Do.
48	5H	1, 300	do	do	70	4	2½	8		⅝	6	¼	6	do	Fractured at 5 feet.
49	5H	2, 300	Asbestos-brick base.[3]												
50	5H	2, 400	Brick	Square	50	5		13		NA	NA	NA	NA	None	Sheared off at 30 feet.
51	5I	3, 200	Concrete	Circle	50	4	2½	12		⅝	6	¼	6	do	None.
52	5I	3, 800	Brick	Square	50	6½		13	9	NA	NA	NA	NA	do	Sheared off at 30 feet.
53	5I	3, 900	Steel, brick	Circle	70	1	1	⅛	⅛	NA	NA	NA	NA	Steel portion 40 feet high; brickbase 3 feet square, 30 feet high.	Steel portion sheared off.
54	5I	4, 000	Concrete	do	75	3½	1½		3	½	4	1/16	6	None	Sheared off at 55 feet.
55	5J	5, 900	Tile-brick base[3]												
56	5J	6, 000	Concrete	Circle	80	4	2	6		⅝	6	⅜	8	None	None.
57	5J	5, 600	do	do	86	9	6							Square base, 40 feet high, integral with building.	Do.
58	4J	5, 400	Steel	do	50	1⅔	1¼	¼	¼	NA	NA	NA	NA	Lap-welded joints	Do.
59	4I	5, 300	Concrete	do	70	5	2							None	Do.
60	3I	6, 300	Brick	Square	50	5				NA	NA	NA	NA	do	Sheared off at 30 feet.
61	3I	5, 000	Tile-concrete base.[3]												
62	4I	5, 200	Brick base	Circle	60	1¼	1¼	¼	¼	NA	NA	NA	NA	Lap welded joints, base 3¼ feet square, 16 feet high.	Steel portion sheared off.
63	5J	6, 600	Steel-brick base	do	54	1½	1½	¼	¼	NA	NA	NA	NA	Riveted joints, base 4⅔ feet, octagonal 38 feet high.	Do.
64	5J	6, 900	Concrete	do	96	7	3							None	None.
65	5J	7, 300	Brick	Square	45	5	3½			NA	NA	NA	NA	Vertical and diagonal angle-iron braces.	Do.
66	5J	8, 100	Concrete	Circle	120	8	5							None	Do.

[1] 14 gage.   [2] ¼-inch mesh.   [3] Disregarded.

TYPICAL UNDAMAGED STACKS

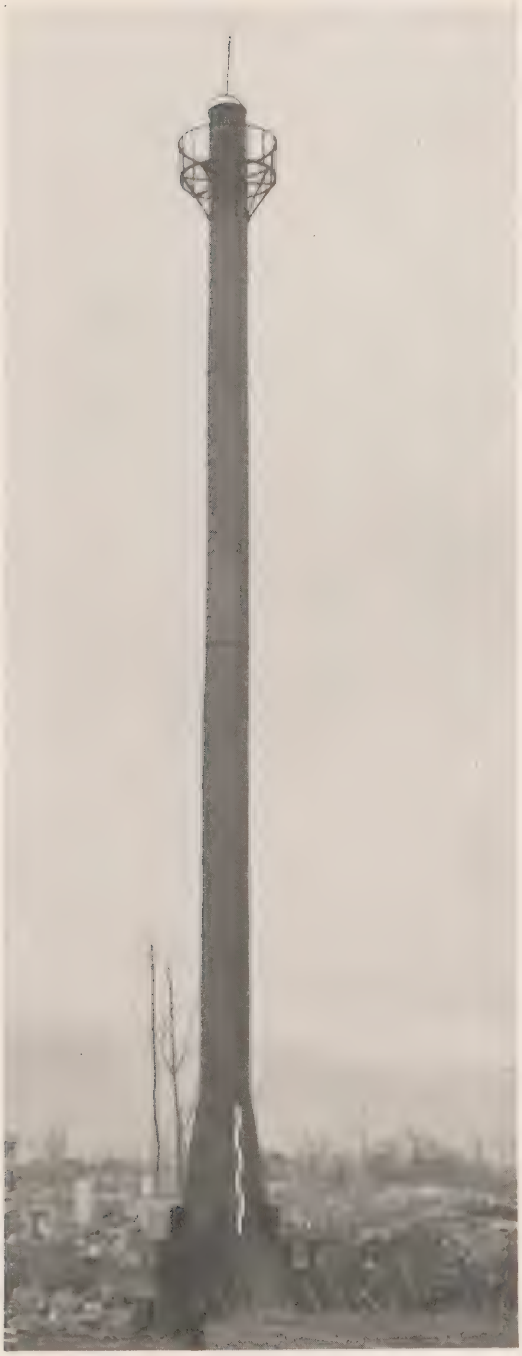


PHOTO 1–XIV. Stack 9. Typical steel stack with brick base.

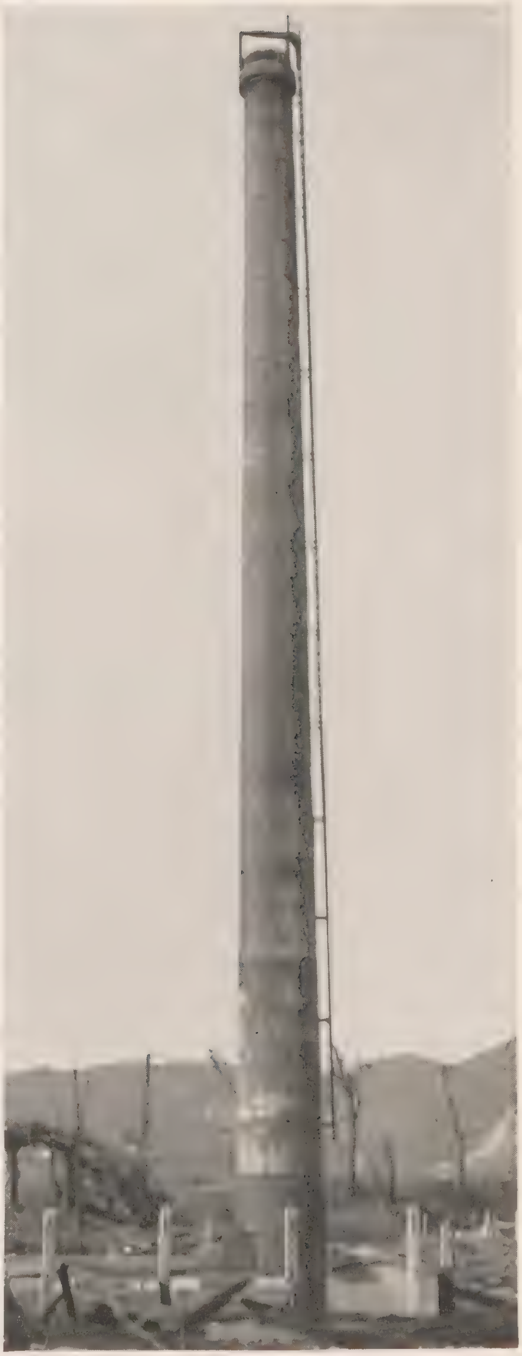
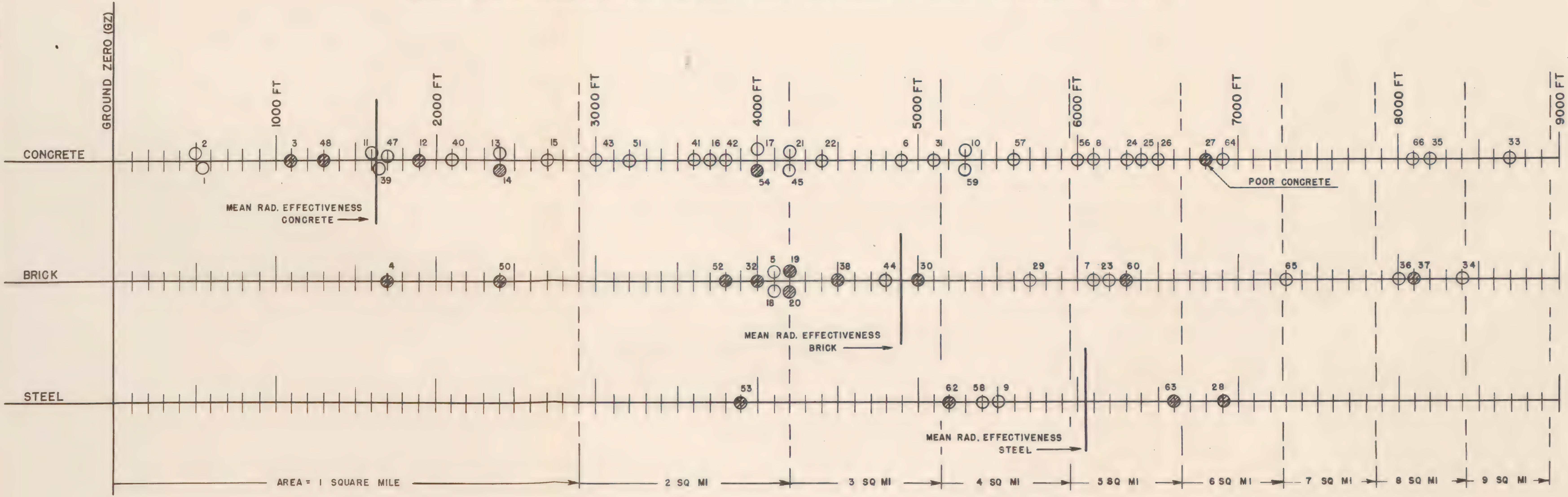


PHOTO 2–XIV. Stack 10. Typical reinforced-concrete stack.

SECRET

GRAPHIC SUMMARY OF DAMAGE TO STACKS

SHOWING LOCATION OF CONCRETE, BRICK AND STEEL STACKS WITH RESPECT TO DISTANCE FROM GROUND ZERO (GZ)



LEGEND

○ – UNDAMAGED, OR USEABLE WITH MINOR REPAIR

● – COMPLETLY DESTROYED, OR REQUIRING REBUILDING

CONCLUSIONS

	MEAN AREA OF EFFECTIVENESS	MEAN RADIUS OF EFFECTIVENESS
CONCRETE	0.3 SQ MI	1625 FT
BRICK	2.7 SQ MI	4900 FT
STEEL	4.1 SQ MI	6050 FT

SECRET

U.S. STRATEGIC BOMBING SURVEY

DAMAGE TO STACKS
HIROSHIMA, JAPAN
FIGURE I- XIV

PHOTO 3–XIV. Stack 5. Typical square brick stack.

PHOTO 4–XIV. Stack 36. Typical octagonal, brick stack.

PHOTO 5–XIV. Stack 3. Reinforced concrete, 1,100 feet from GZ.

PHOTO 6–XIV. Stack 14. Reinforced concrete, 2,400 feet from GZ, with 1½-inch heating pipes protruding from base.

PHOTO 7–XIV. Stack 48. Fractured, reinforced-concrete stack, 1,300 feet from GZ.

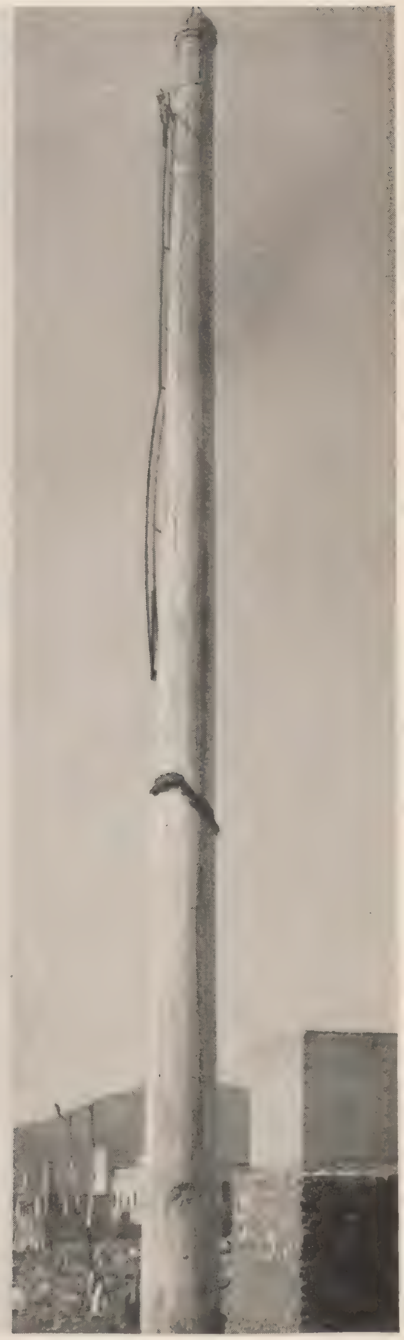


PHOTO 8–XIV. Stack 48. General view of stack shown on Photo 7.

PHOTO 9–XIV. Stack 27. Reinforced concrete 6,800 feet from GZ.

PHOTO 10–XIV. Stack 54. Reinforced concrete, 4,000 feet from GZ. Sheared off at 55 feet.

PHOTO 11–XIV. Stack 12. Reinforced concrete, 1,900 feet from GZ. Fractured at 16 feet

PHOTO 12–XIV. Stack 38. Square, brick, 4,500 feet from GZ. Sheared off at 30 feet. Note angle-iron bracing.

PHOTO 13–XIV. Stack 4. Hexagonal brick, 1,700 feet from GZ. Sheared off at 12 feet.

PHOTO 14–XIV. Stacks 19 and 20. Square, brick, 4,200 feet from GZ. Sheared off at 35 feet.

PHOTO 5–XIV. Stack 30. Square, brick, 5,000 feet from GZ. Sheared off at 35 feet.

PHOTO 16–XIV. Stack 32. Square, brick, 4,000 feet from GZ. Sheared off at 20 feet.

PHOTO 17–XIV. Stack 37. Square, brick, 8,100 feet from GZ. Sheared off at 20 feet.

PHOTO 18–XIV. Stack 50. Square, brick, 2,400 feet from GZ. Sheared off at 30 feet.

PHOTO 19–XIV. Stack 25. Square, brick, 3,800 feet from GZ. Sheared off at 30 feet.

PHOTO 20–XIV. Stack 60. Square, brick, 6,300 feet from GZ. Sheared off at 30 feet.

PHOTO 21–XIV. Stack 62. Steel with brick base, 5,200 feet from GZ. Failed at anchorage to base.

PHOTO 22–XIV. Stack 28. Steel with brick base, 6,900 feet from GZ. Failed at anchorage to base.

SECTION XV
PHOTO INTERPRETATION

1. Object of Study

The objective of this section of the Hiroshima Physical Damage Report is (1) to recommend technical changes in photographic interpretation techniques necessitated by the use of the atomic bomb; (2) to study the characteristics of atomic-bomb damage which will be apparent on aerial photographs; (3) to evaluate the accuracy of intelligence reports based on photographic coverage of the Hiroshima area; and (4) to comment on the value of photographic interpretation to a ground survey.

2. Summary

a. New techniques or variations of existing ones which will take into consideration the integrated industrial, military, commercial and domestic activities and the diverse structural types which comprise an area under analysis as an atomic-bomb target must be developed for both preattack and postattack intelligence reports.

b. Although there are some distinctive characteristics of damage which result from an atomic-bomb attack, they are similar to those which have been associated with previous weapons, and the two basic causes of damage, blast and fire, can be identified by current photographic interpretation techniques.

c. The Physical Damage Report on Hiroshima prepared by the Joint Target Group was generally correct in description of the damage, but was inaccurate in respect to certain details: Ground zero of the blast was mislocated by approximately 1,130 feet; the reported area of total damage was substantially correct, the mean area of effectiveness (MAE) of the bomb was slightly overestimated; and the reported damage to concrete buildings did not correspond to the findings of the ground survey.

d. The photographic intelligence study of the Japan Steel Works, Ltd., reported correct, or closely allied, occupancy to buildings comprising 90 percent of the total plant area and gave a reasonably accurate description of the vulnerability of the plant to blast damage, but underestimated the vulnerability of the target to fire.

e. General information concerning Hiroshima as a military target was relatively accurate. Few reports had been prepared on the area and the amount of intelligence information was limited, since the city was neither one of the primary urban targets, nor was it highly industralized.

f. Photographic intelligence has proved a definite aid to ground survey groups in establishing the validity of interrogations, checking the status of the target on specific dates prior to the arrival of the field survey, and as guide and index for the area.

3. General Information

It is the opinion of the members of the team that the factual information presented herein is accurate and in sufficient detail to warrant the recommendations and conclusions which are reached.

a. Part 3 of this section is an evaluation of the accuracy of a physical damage analysis prepared by the Physical Vulnerability Section, Joint Target Group, dated 1 September 1945, as Special Project PV–P82. A complete copy of this report is filed with G–2, U. S. Strategic Bombing Survey.

b. Part 4 is an evaluation of the accuracy of an industrial photographic interpretation report on the Japan Steel Works, Hiroshima Branch, prepared by AC/AS Intelligence, Photographic Division, as Buildings Construction Analysis (BCA) No. 60, dated 9 June 1945. A copy of this report is filed with G–2, U. S. Strategic Bombing Survey.

c. Part 5 is an attempt to evalute the preattack general target information concerning the city of Hiroshima. As a basis for study CINCPAC-CINCPOA Bulletin No. 8–45 of 15 January 1945, entitled "Air Information Summary," and Interpron Two Report No. 576 of 10 May 1945 were used. Since Hiroshima was not indicated as a target of primary importance, no detailed preattack urban analysis was done on the city.

PART 1. INFLUENCE OF THE ATOMIC BOMB ON PHOTO INTERPRETATION

1. By the close of World War II, photographic interpretation had developed into one of the most important sources of intelligence concerning the enemy, his resources, plans, and action. In connection with the strategic bombing program, it was especially important in locating and identifying important targets, in determining the vulnerability of such targets to weapons available, and later in assessing the physical damage to the targets. The extensive use of photographic intelligence resulted in the development of certain techniques for obtaining necessary target information; with the advent of each new weapon or tactic a new technique was required. For instance, when area incendiary attacks were begun, photographic interpreters were called upon to determine combustibility and built-upness of areas, to locate

firebreaks and fire walls, and the like, factors which would affect the number and type of distribution of bombs to be dropped. Many of these data had not been required for high-explosive, "pin-point" bombing used prior to this time. The use of the atomic bomb requires additional changes in photographic interpretation techniques.

2. Basically an atomic-bomb attack is an attack by a single, highly effective bomb which will cause damage to an extensive built-up area comprising, singly or in combination, urban, industrial, and military concentrations. The concept of an attack which affects the integrated activities of a target area is prerequisite to the analysis of the changes in photographic intelligence techniques suggested.

a. Preattack Analysis. (1) The concept of a target must be revised to comprise an area of integrated activities rather than an individual building, individual plant, or single military installation.

(2) A suitable method must be developed for evaluating the economic vulnerability of a target area, which will take into consideration the integrated industry, transportation, services, utilities, and housing which would be affected by attack.

(3) A suitable method must be developed for evaluating the physical vulnerability of a target area, one which takes into consideration the diverse structural types and the mean area of effectiveness of an atomic bomb to each, assuming the aiming point is known.

(4) A suitable method must be developed for the relative evaluation of different possible aiming points with respect to both economic and physical vulnerability of the target.

b. Damage Assessment. (1) The over-all pattern and extent of damage to an urban concentration resulting from an atomic-bomb attack differs somewhat from those resulting from an attack by high-explosive or incendiary weapons, but the characteristics of damage to an individual structure remain unchanged as far as photographic evidence is concerned. Therefore, no basic change in interpretation techniques is required, but more rapid methods of analyzing the economic and physical damage to an area will be necessary.

PART 2. CHARACTERISTICS OF ATOMIC-BOMB DAMAGE AS SEEN ON AERIAL PHOTOGRAPHS

1. A study of the damage to Hiroshima gives evidence of certain characteristics which can be associated with the atomic bomb. A review of these will be a guide to photographic interpreters in identifying and analyzing similar instances of damage. Blast and fire are the causes of damage, and, when present separately, have distinctive appearances on photographs, regardless of the type of weapons used. It is very difficult, however, to differentiate between the two distinctive types of damage when fire has occurred to a blast-damaged area, as was the case at Hiroshima.

2. In analyzing damage it is always necessary to approach the problem with the pattern in mind of the usual or expected reaction of the weapon used in the attack. At Hiroshima, the bomb exploded about 2,000 feet above the heart of the city and destroyed approximately 4 square miles of built-up area. Around this area of complete devastation, in which only earthquake-resistant buildings were left standing, were concentric areas of decreasing damage, ranging from structural to minor. Fire contributed to the damage by consuming most of the buildings collapsed by blast, and, in places, spread of the fire destroyed others not structurally damaged by blast. In many instances, therefore, the fire fringe coincided with the fringe of total damage. Minor blast damage, including extensive glass breakage and some wall and roof stripping, extended as far as 4 miles from ground zero; and in a lesser degree as far as 7 miles.

3. The effectiveness of the atomic bomb is largely due to blast. The blast damage resulting from an ordinary high-explosive bomb with a much smaller mean area of effectiveness is characterized by a radial appearance of the damaged members and debris extending outward from the center of damage. Damage resulting from the atomic bomb has the same characteristic appearance, but because of the much broader area affected, it is not so distinctly apparent. The concentric circles of damage, previously mentioned, reflect this characteristic, but the regular pattern of damage is often interrupted by topographic features. In good-quality, large-scale photographic coverage, it is likely that other evidence of the radial appearance can be seen. Some of these would include streetcars displaced from rails, overhanging cornices broken, bent flagpoles and utility poles, and collapsed walls, all of which will be directionally away from the center of damage. When this evidence is properly evaluated it may aid in locating the approximate ground zero or center of damage.

4. The fire damage resulting from an atomic-

bomb attack does not differ in appearance on aerial photographs from that of an ordinary incendiary attack but the pattern of the fire fringe does differ somewhat. In an incendiary attack, the windward boundary of the fire fringe will usually be jagged and irregular, and beyond the fringe there will be many isolated cases of small fires caused by the "spill-over" of the attack, which were controlled by fire fighting. On the leeward edge, it is more difficult to fight the conflagration because of the intense heat and smoke; consequently, the fire usually burns unchecked until it reaches a firebreak or area of low built-upness. This results in a fire fringe that is more regular than on the windward side, where fire fighting could partially control the blaze.

5. The pattern of the fire fringe in the case of the atomic-bomb attack on Hiroshima tended to be more regular on all sides because fire originating in a large area around the center of damage was so intense that the air was drawn inward from all directions, and, therefore, fire was less likely to spread outward and make indentations into the unburned area. This phenomenon would have been unlikely if a moderate or strong natural wind had been blowing at the time of attack; in that case the pattern of the fire fringe would probably have reflected the more normal spread of fire to leeward. Although some instances of isolated fires occurred outside the fire fringe, they were noticeably less numerous than would result from an incendiary attack, when ignition can be attributed to "spill-over."

6. The limits of the fire are important in damage assessment, as was demonstrated in Hiroshima where nearly all concrete buildings left standing within the fire fringe were gutted by fire, and severe damage was caused to machine tools and other equipment in industrial structures.

7. Color photography would increase the accuracy of fire-damage assessment, if it were more extensively used. Color photography of Hiroshima showed the burned-over area to be more red than the remainder of the damaged area.

PART 3. EVALUATION OF PHOTOGRAPHIC INTERPRETATION PHYSICAL DAMAGE REPORT

1. The damage to Hiroshima City resulting from the atomic-bomb attack of 6 August 1945 is the subject of a report issued by the Physical Vulnerability Section of the Joint Target Group. The report was based on a study of photographic sortie 3PR–5M391 of 9 August 1945, and is a general, preliminary analysis giving a close approximation of the damage incurred by the city. The following subsections are a check of various parts of this report.

2. *Ground Zero.* *a.* The location of the ground zero as estimated by the Joint Target Group report was approximately 1,130 feet to the northeast of the actual ground zero. The reported probable degree of error was plus or minus 500 feet.

b. The atomic bomb dropped on Hiroshima detonated about 2,000 feet in the air and consequently left no crater to establish the point of explosion. The reported ground zero was apparently located by determining the center of the roughly circular area of total destruction in the heart of the city. As no data on the attack were available at the time, this method appears to be the only one possible under the circumstances, but the fact that such a large error resulted indicates that this method is not reliable. It would only be reliable when the area affected was equally vulnerable in all directions, and the resultant fire spread equally in all directions. The survey determined the actual ground zero by examination of flash marks, and flash shadows, none of which would be apparent in aerial photos. Other indications of blast direction, i. e., the leaning of buildings, damaged sides of buildings, and overturned street cars, might be apparent in photographs under certain circumstances, but "exceptions to the rule" and unusual examples would probably prevent anything but a rough approximation of the actual ground zero.

3. *Area of Damage.* *a.* The 4-square-mile area of virtually total destruction reported by the Joint Target Group is substantially correct. One small area of additional damage (0.048 square mile) was beyond the limits of the photographic coverage available for the report.

b. No exact figure for the total area of damage was given in the report due to quality of cover. In lieu thereof, the percentages of damage at various distances from the ground zero were given, and these were based on damage to the larger buildings in the more important industrial, military and public installations. In support of this method the report states that:

> Although the larger buildings* presented a larger area to the blast wave and hence might be expected to receive

*"Larger buildings" refers to industrial and storage buildings other than those reported as concrete buildings.

more damage than smaller buildings, on the other hand, the larger buildings are stronger and less vulnerable than the smaller buildings which are chiefly residences * * * these two effects largely cancel each other.

It is the opinion of the members of this team that such reasoning does not hold for this particular case because many of the "larger buildings" which were examined exhibited a much greater vulnerability to damage than residential type structures. The "larger buildings" which were prevalent throughout Hiroshima were chiefly wood-frame, industrial-type buildings and were extremely vulnerable to blast. Enough of them were included in the calculations of the Joint Target Group report to affect the accuracy of the results. The mean area of effectiveness for these two specific types of structures is given in Part 3, Paragraph 6*c*, and reflects the opinion expressed above.

c. The Joint Target Group report tabulated the area of damage by urban area zones in the central area of damage. The zones depended upon the built-upness and occupancy assigned by photo interpreters from prestrike cover. The accuracy of these zones could not be checked on the ground because of the complete devastation and because no reliable Japanese documents furnishing this information were recovered.

4. *Check on Damage to Concrete Buildings.* *a.* When viewing the damage photographs of Hiroshima, one immediately notices reinforced-concrete buildings standing apparently undamaged throughout the area of total destruction. This significant point was given some prominence in the Joint Target Group report. A study was made from preattack and postattack photos to determine the number and location of concrete buildings and extent of damage sustained by them as a result of the atomic-bomb attack. Table 1 from the report shows the result of this study.

b. Table 2 was compiled from data gathered at the site. The buildings included therein comprise all of the reinforced-concrete structures (plus those of composite steel and reinforced-concrete frame) found in the city, three of which were beyond the limits of the blast and fire studies. No direct comparison is made between these figures and those given in Table 1. It is the opinion of the team that only the damage in the first two categories, i. e., 100 percent structural damage and 50–99 percent structural damage, could have been determined with any degree of accuracy from the photographic coverage used for the report. The actual physical damage to buildings is given here with respect to distance from ground zero, which was the basis for the reported figures in Table 1.

TABLE 1.—*Reported damage to concrete buildings*

Distance from center of impact	Total number of buildings	Number partly destroyed	Number completely destroyed
0 to 1,000 feet	10	1	1
1,000 to 2,000 feet	13	1	0
2,000 to 3,000 feet	5	0	0
3,000 to 4,000 feet	7	0	0
4,000 to 5,000 feet	3	0	0
5,000 to 6,000 feet	10	1	1
6,000 to 7,000 feet	0	0	0
7,000 to 8,000 feet	0	0	0
8,000 to 9,000 feet	1	0	0
9,000 to 10,000 feet	0	0	0
10,000 to 11,000 feet	1	0	0
Beyond 11,000 feet	0	0	0
Total	50	3	2

TABLE 2.—*Actual damage to concrete buildings*

Distance from Ground Zero	Number of buildings	100 percent structural damage	50–99 percent structural damage	1–49 percent structural damage	No structural damage
0–1,000 feet	9	0	2	5	2
1,000–2,000 feet	14	3	1	8	2
2,000–3,000 feet	9	0	0	2	7
3,000–4,000 feet	7	0	0	0	7
4,000–5,000 feet	9	0	0	0	9
5,000–6,000 feet	9	2	1	1	5
6,000–7,000 feet	4	0	1	0	3
7,000–8,000 feet	3	0	0	0	3
8,000–10,000 feet	10	0	0	0	10
Total	74	5	5	16	48

c. Identification of Concrete Buildings. Twenty-five of the seventy-four reinforced-concrete buildings in the city were not identified as such in the Joint Target Group report. Usually this type of building is easily identifiable in Japanese cities by the typical flat concrete roof slab. An examination of the photographic coverage used for the report indicates the following possible reasons for this discrepancy:

(1) Nine buildings were too small to be identified or considered of importance.

(2) Four buildings had gable roofs with tile covering.

(3) Two buildings had saw-toothed roofs.

(4) One building was not covered by photography.

(5) Nine buildings were apparently overlooked. (Only two buildings were incorrectly identified as being constructed of reinforced concrete, and both had flat, concrete-slab roofs, supported by load-bearing, masonry walls.)

d. Damage to Structures. (1) Of the five buildings suffering 100-percent structural damage, the damage to one building was correctly assessed; three buildings were not identified as concrete and therefore not assessed; and one building was marked undamaged.

(2) Of five buildings 50–99 percent structurally damaged, the damage to one building was correctly assessed; and no damage was assessed on four buildings. (Two other buildings reported as partly destroyed actually sustained only minor damage.)

e. Damage to Contents. It is impossible from vertical photographs to assess internal damage to buildings, the roofs of which remain intact, and no attempt was made to do so in the Joint Target Group report. It is felt, however, that it will be of interest to show the figures since practically all concrete buildings within the badly damaged area of the city did suffer internal damage from fire.

TABLE 3.—*Damage to contents*

Number of buildings:	*Fire damage to contents (percent)*
39	100
15	50–100
3	0– 50
17	0

NOTE.—All but 6 buildings were within the burned area.

An examination of large-scale, oblique coverage of Hiroshima failed to show evidence of this extensive fire damage to the interiors of the buildings. Such damage could be detected in only a few cases despite the fact that these photographs were taken under ideal conditions after the close of hostilities.

5. *Check on Functional Assignments.* In the Joint Target Group Report, 67 installations were annotated and given functional identifications, 51 of which were checked by the Survey. These identifications were derived from all available sources of intelligence (mainly ground information and photographic interpretation). Since photographs are usually used to substantiate ground information, all such identifications are considered in the following check. It should be noted that the city of Hiroshima was not considered a priority, strategic-bombing target until the atomic-bomb attack and no comprehensive intelligence study had been made of the target.

TABLE 4.—*Functional identification*

Type of identification:	*Number of installations*	*Percent of total*
Identified correctly	26	50.9
Identified incorrectly	11	21.6
Given similar identification	4	7.9
Unidentified by P. I. report	10	19.6
Total	51	100.0

6. *Mean Area of Effectiveness (MAE). a.* The MAE of a weapon is the probable area of a given type and degree of damage which would result, if the weapon were used against an area of unlimited extent, completely built-up with targets of the specific type and construction under consideration.

b. The Joint Target Group reported the MAE for superficial damage to average, single and multistory buildings to be 10.1 square miles with the Hiroshima atomic bomb.

c. The MAE's of this bomb for structural damage determined by this team (Sec. X) are as follows

TABLE 5.—*Mean areas of effectiveness*

Type of construction	Vulnerability	MAE (square miles)	MAE radius (feet)
Multistory, earthquake-resistant	VI	0.03	500
Multistory, steel- and R. C.-frame (including earthquake-resistive buildings)	V3; V1	.05	700
Light, steel-frame	V4	3.4	5,500
Multistory brick	V3A	3.6	5,700
Domestic construction (residential)	V4	6.0	7,300
One story brick	V4	6.0	7,300
Wood-frame, industrial-commercial construction	V3; V4	8.3	8,700
Wood-pole construction	V3; V4	9.5	9,200

d. Since the reported MAE was figured for superficial damage and the team's MAE was for structural damage no direct comparison of the two can be made. Moreover, many of the buildings (particularly the wood-pole and the wood-frame, industrial-commercial types of construction) reported by Joint Target Group as being of V3 and V4 vulnerability were found to be much more vulnerable than the average buildings in these two categories.

e. It should be pointed out that in Hiroshima domestic structures were less vulnerable than the most prevalent of the V3 and V4 buildings, namely, the wood-frame, industrial-commercial and the wood-pole construction types.

f. It is inadvisable to attempt to compute an MAE from aerial photographs, unless the quality of the cover permits reasonably accurate determination of building types. This is exemplified by the extreme variation of the MAE's shown in Table 5 for V3- and V4-type buildings for which one MAE was reported by Joint Target Group.

PART 4. EVALUATION OF PHOTOGRAPHIC INTERPRETATION INDUSTRIAL REPORT

1. The only target in the vicinity of Hiroshima on which industrial interpretation reports were made was the Japan Steel Co., Ltd., Hiroshima Branch (Target No. 90.30–1891).

a. The photographic intelligence functional analysis report on this target assigned correct or closely allied occupancy to approximately 90 percent of the total plant area.

b. The photographic intelligence structural analysis report gave a reasonably accurate description of the target as regards vulnerability to high-explosive attack. The vulnerability of the target to fire was considerably underestimated, principally because of the prevalence of wood sheathing and framing members under noncombustible roof covering. The only general error in the assignment of building construction classifications concerned buildings housing overhead traveling cranes, where the capacity of the cranes was greatly overestimated.

c. The 6 August 1945 atomic-bomb attack inflicted some damage to the plant which was located approximately 4 miles from ground zero of the atomic bomb. There was no structural damage and no loss of production as a direct result of physical damage; however, production was stopped for ten days while company personnel participated in emergency relief work in the urban area.

2. *Description of the Target. a.* The Japan Steel Works, Ltd., Hiroshima plant (Fig. 1), was located approximately 4 miles east-southeast from the ground zero on the seaward side of the Hiroshima-Kure coastal highway. The total site area was 220 acres and the plant comprised 80 installations (74 of which were buildings) of functional importance arranged in an irregular pattern between the highway and Ujina Ko.

b. The plant consisted of three general areas of production, the largest area being devoted to fabricating and machining Army and Navy ordnance items other than ammunition. The principal products of this section of the plant were guns of sizes up to 40-caliber, 12.7-millimeter antiaircraft, torpedo discharge tubes, various special forgings and castings for gun turrets, and shells.

c. The second area, on the waterfront in the southern section of the plant, fabricated and assembled submersible transports (large submarines) for the Army.

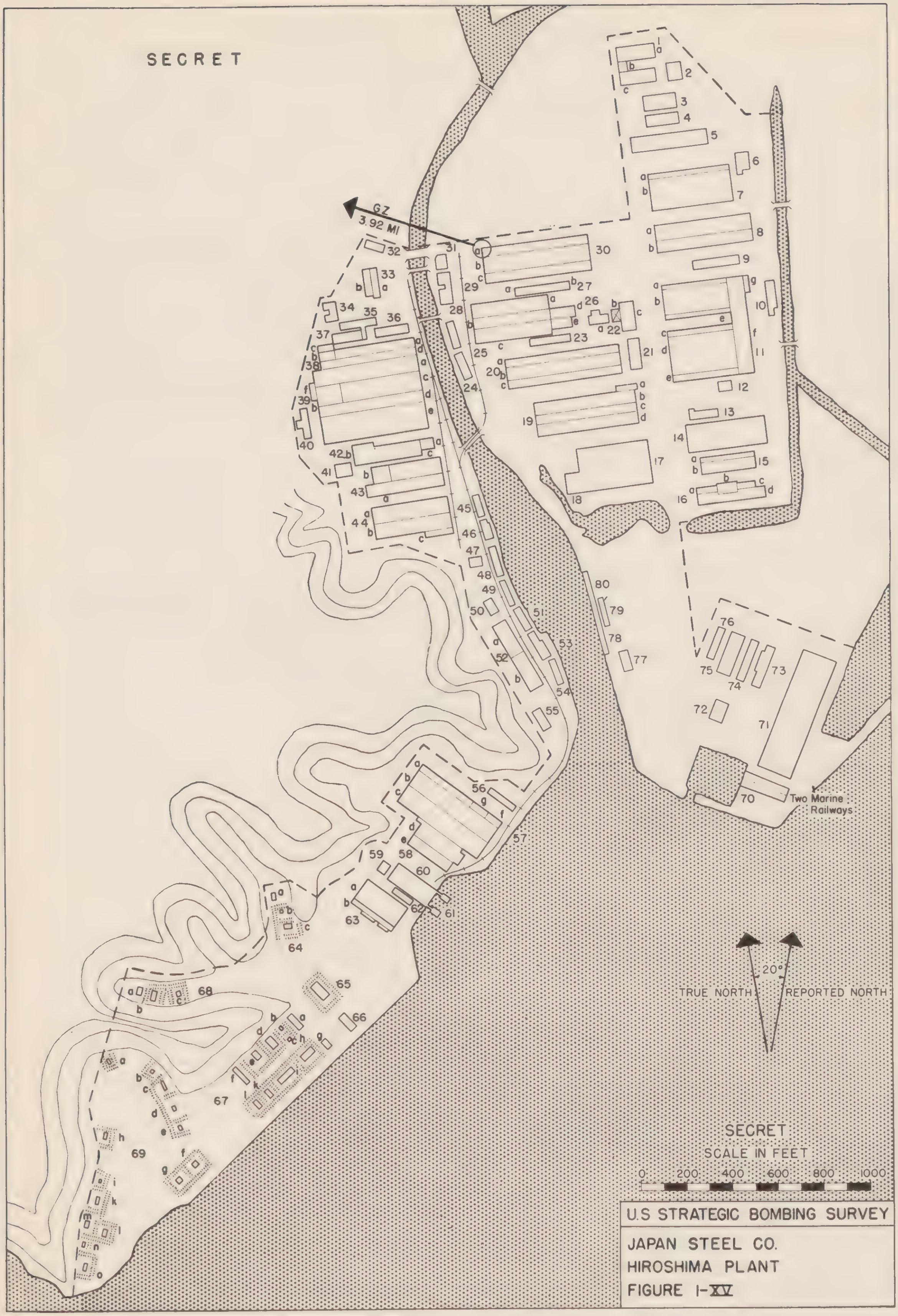
d. The third area, in the southeasterly section of the plant on the narrow coastal strip at the foot of a steep rise, produced 25-millimeter ammunition, including explosives, cartridges, and percussion fuses.

e. Nonmilitary products produced were reaction and mixing tanks for nitrogen fixation and railroad coupling shock absorbers.

f. A large part of the raw materials were supplied by the Army and Navy and were machined and assembled at the plant.

3. *Description of Damage. a.* No attack, air or surface, was directed against this company's plant; the slight damage, hereinafter described, resulted from the atomic-bomb attack against Hiroshima on 6 August 1945. No structural damage was sustained by the plant, but superficial or minor damage occurred to all major buildings. All damage was due to blast; no fires were started. No interruption of processes nor damage to vital machinery resulted from the physical damage to the plant; but because of wide devastation in the Hiroshima area, production was halted to expedite emergency relief for 10 days, 6–15 August 1945.

b. The day of the attack was a company holiday and only a bare skeleton crew was at the plant. Casualties to employees, many of whom lived in Hiroshima, were consequently greater than it otherwise would have been.


SECRET
GZ
3.92 MI
Two Marine Railways
TRUE NORTH
REPORTED NORTH
20°
SECRET
SCALE IN FEET
0 200 400 600 800 1000
U.S STRATEGIC BOMBING SURVEY
JAPAN STEEL CO.
HIROSHIMA PLANT
FIGURE I-XV

c. The following tabulations prepared by the company show the damage resulting from the atomic bomb. Damage to the small Nisikaniya branch factory building located near the railway station in central Hiroshima is included in the following tabulation, which erroneously gives the impression of a high percentage of damage to the main plant itself.

TABLE 6.—*Damage to Japan Steel Co., Ltd.*

Damage to property:

(*a*) *Factory:* Percent

Roof	20
Wall*	90
Glass	95

N. B. Nisikaniya branch factory badly damaged.

(*b*) *Dormitory and factory houses:* Percent

Roof	10
Wall*	30
Glass	60

(*c*) *Machinery and equipment:*

Machinery, electric power, water mains. Minor damage.

Casualties up to 27 September 1945:

(*a*) *Employees:*

Killed	376
Seriously injured	212
Slightly injured	249

N. B. Total number of employees, 5 August, 18,082.

(*b*) *Employees' families:*

Killed	520
Seriously injured	516
Slightly injured	676

Expenditures:

Special payments, food, clothing, medical care, 631,475 yen.

Production losses:

From 6 to 15 August, factory production was halted and employees were put on relief restoration work. Losses are estimated as follows:

Man-hours lost, 261,680	¥130, 840
Production	1, 600, 000
	¥1, 370, 840

*Nonstructural damage except at Nisikaniya.

d. The most extensive damage to any one building was observed at Building 30 (Fig. 1). The three bays on the opposite end of the building from the center of blast sustained roof stripping and a few wood purlins were broken. Both end walls were stripped, steel sash were distorted and glass was broken. The building was closed at the time of the attack.

e. It was found in general that the heaviest damage occurred at the ends of buildings away from the center of blast. It consisted of wall and roof stripping, glass breakage, deformation of metal sash, and some fracture of light, wooden, intermediate, framing members. Almost all indications of blast were outward from the building, and the most severe damage occurred to the buildings tightly closed to the elements. The small revetted buildings in the explosive-manufacturing area were undamaged except for a very small amount of glass breakage.

4. *Functional Analysis Evaluation*. This evaluation is based on the occupancy reported by the Joint Target Group for analyzing the functional importance of each building in the plant.

a. *Boundaries*. The boundaries as reported were substantially correct, and included all the productive parts of the plant. The administrative area in the northern corner was not included (this area contained the bulk of the general office space, student dormitories, and classrooms).

b. *Building Identification*. The accuracy of individual building occupancy identification is tabulated as follows:

TABLE 7.—*Building identification*

Type of identification	Number of buildings	Area (square feet)	Percent total area
Identified correctly	36	830. 7	58. 2
Of similar occupancy	17	396. 6	31. 0
Unidentified in report	6	38. 2	3. 4
Wrongly identified	15	102. 4	7. 4

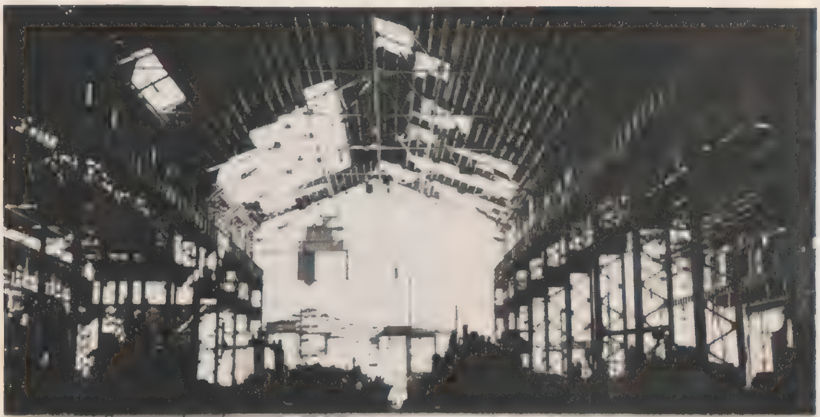
(1) The tabulation shows that apparently no cognizance was taken of the fact that in Japanese industrial lay-out, service buildings (e. g., employees' cloak rooms and mess halls) were often found adjacent to the large shop buildings, and, as a result, these service buildings were misidentified as warehouses.

(2) In this plant the production flow line was not sufficiently straightforward to deduce from relative position in the layout the process in each building.

c. *Services*. The plant was serviced by rail, highway, and lighterage.

d. *Area of Plant*. The total area of land owned by the company was 220 acres. The reported area of the target was 143 acres. The land owned by the company included wooded and rough-terrain areas not suitable for industrial purposes, which were correctly excluded from the reported target area.

PHOTOS 1–XV and 2–XV. Building 20 (Fig. 1–XV). No damage other than glass breakage and distorted window frames occurred to this modern concrete roofed industrial building.



PHOTOS 3–XV and 4–XV. Building 30 (Fig. 1–XV). Interior and exterior views of this light steel framed industrial structure, show the character and extent of roof and sidewall stripping.

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PHOTO 5–XV. Building 24 (Fig. 1–XV). This light, wood-framed, one-story structure, covered with stucco, was blown about 12 inches out of plumb by the bomb blast, but its usefulness was unimpaired.

PHOTO 6–XV. Building 71 (Fig. 1–XV). The submersible transport assembly building, in the southeastern part of the plant, sustained some wall stripping.

PHOTO 7–XV. This general view shows the uniformity of superficial damage to the buildings in the plant area.

5. *Structural Analysis Evaluation. a. Scale.* An average error of 3 percent was found after checking reported dimensions against ground dimensions.

b. Orientation. The north indicated on the target plan was found to be approximately 20 degrees east of true north.

c. Building Construction Types. The Joint Target Group building construction analysis section has established a classification system for structures, based on distinctive differences in design of the usual industrial-type buildings. The classification system, shown in Reference Tables, takes into consideration the basic design of the structure, truss or girder span, column height, number of floors, and resistance to shock loading.

(1) Correct building-type classification was reported by the Joint Target Group for 56 buildings, representing 49.5 percent of the plan area; 21 buildings, representing 50.5 percent of the plan area, were incorrectly classified. Of those incorrectly classified, 10 buildings, representing 39.0 percent of the plan area, were reported as B1 type and were actually B2 type. The difference between B1 and B2 construction types is in the capacity of the overhead traveling crane only.

(2) Table 8 compares the reported and actual areas in each building construction classification.

TABLE 8.—*Reported and actual construction types*

Building construction classification	Reported: Number of buildings	Reported: Area (thousand square feet)	Reported: Percent of total	Actual: Number of buildings	Actual: Area* (thousand square feet)	Actual: Percent of total
A1.1	2	59. 1	4. 3	4	78. 8	5. 8
A2.3	8	199. 7	14. 5	7	100. 0	7. 3
B1	10	522. 4	38. 2	1	15. 0	1. 1
B2	6	365. 1	26. 7	17	957. 6	70. 3
D	46	182. 7	13. 3	38	159. 9	11. 6
E2	6	39. 9	2. 9	9	53. 9	3. 6
F2	0	0	0	2	3. 7	. 3

* Based on the Joint Target Group reported building areas for comparison.

d. High-Explosive Vulnerability Factors. The Joint Target Group classification system for blast vulnerability of industrial structures is based directly on classification of building-construction types explained in subsection *c* above. Vulnerability varies from V1 to V5, most resistant to least resistant, respectively.

(1) A total of ten buildings, representing 12.8 percent of the total plan area, were assigned a wrong vulnerability factor. Although the high-explosive vulnerability factor depends directly on the building construction type, several building types carry the same vulnerability factor. Such is the case with B1- and B2-type buildings, each of which carries a V2 vulnerability rating. This accounts for the smaller percentage of error than was made in assignment of building construction types.

(2) Table 9 gives the reported and actual floor areas for each high-explosive vulnerability factor.

TABLE 9.—*Reported and actual HE vulnerability*

HE vulnerability factor	Reported: Number of buildings	Reported: Area (thousand square feet)	Reported: Percent of total	Actual: Number of buildings	Actual: Area* (thousand square feet)	Actual: Percent of total
V2	16	887. 5	64. 6	18	972. 6	71. 4
V3	6	39. 9	2. 9	9	53. 9	3. 6
V3A	0	0	0	2	3. 7	. 3
V4	56	441. 5	32. 5	49	338. 7	24. 7
Total	78	1, 368. 9	100. 0	78	1, 368. 9	100. 0

*Based on the Joint Target Group reported areas for comparison.

e. Combustibility Factors. A total of 17 buildings, representing 48.0 percent of the total plan area, were assigned incorrect combustibility ratings. All errors were in reporting combustible buildings as noncombustible. A building is rated as combustible (C) if either or both main frame or covering (roofing or siding) is of a material which will in itself support combustion; rated noncombustible (N) if, although the materials will not support combustion, it will be structurally damaged by intense heat; and rated resistive (R) if the materials will neither support combustion nor be affected by heat.

(1) The most common error in this case was in the description of the roof. In most cases the roofing, although noncombustible (either tile or corrugated-asbestos) was over wood roofers. This placed the building in the combustible category. Wood framing was used much more extensively in this plant than in similar industrial plants in the United States. Several instances were found where heavy wood framing was used in buildings housing overhead traveling cranes. Company officials stated that a shortage of steel for wartime construction led to this expedient.

(2) Table 10 compares reported and actual areas of combustibility ratings.

TABLE 10.—*Reported and actual combustibility ratings*

Combustibility rating	Reported		Actual	
	Area (thousand square feet)	Percent of total	Area* (thousand square feet)	Percent of total
Combustible (C)	241. 5	17. 9	1,014. 0	74. 1
Noncombustible (N)	1,127. 4	82. 1	349. 9	25. 9

(No resistive (R) buildings were reported; 2 small substations, not included above were of resistive-type construction.)
*Based on Joint Target Group areas for comparison.

f. Building Heights. Of the 28 buildings checked, results were found as shown in Table 11.

TABLE 11.—*Building heights*

	Number of buildings	Average error	Percentage of buildings	Percentage error (based on building height)
No error	4	None	14	0
Overestimated	9	5. 9	32	20
Underestimated	15	5. 8	54	20

g. Crane Study. Since the greatest error in assigning construction types was made in estimating the capacity of cranes housed in the B-type buildings, a tabulated comparison (Table 12) of the crane capacity to occupancy, span and eave height of 14 buildings was prepared.

h. Building Subdivisions. In most cases buildings were subdivided correctly. No detailed study is necessary.

i. Service Buildings. Several multistory buildings among the production buildings were reported as storage; these were cloak rooms, mess halls, and office space. Story heights varied from 10 to 12 feet. Second story was clear span, while the first-story spans were reduced by columns.

j. Buildings Removed. One steel-frame structure (Building 42, Fig. 1–XV) was in the process of being removed to provide a working area between the forge and foundry. Small combustible buildings were removed to reduce fire hazard; these were all storage buildings. Wood block floors were removed in several machine shops to prevent fire spread.

TABLE 12.—*Crane capacity*

Building No. (Figs. 1–XV)	Crane capacity (tons)	Span (feet)	Eave height (feet)	Occupancy
60	60	75	56	Assembly gun carriage and turrets.
11	15, 10, 5	40	38	Foundry.
58c	15, 10	48	28	Machine shop (gun barrels).
b	15	57	32	Do.
d and e	10, 5	45	23	Do.
14	10, 5	40	38	Scarfing shop.
20b	10	47	38	Machine shop.
39a	10	45	36	Assembly and machine shop.
e	10	33	32	Do.
71	10, 5	45	26	Subtransport fabrication and assembly.
8a	5	60	42	Sheet metal shop.
20a and c	5	40	38	Machine shop.
26	5	35	34	Do.
30	5	42	30	Do.
44	5	27	26	Do.
7	3	57	30	Do.
8b	3	36	42	Sheet metal shop.

A study of this tabulation indicates that the visible characteristics of the buildings do not accurately indicate crane capacity.

k. Camouflage. No extensive camouflage was attempted at the plant. On the roof of Building 20 (Fig. 1–XV) steel filings were spread in a disruptive pattern for camouflage. Company officials stated that this expediency was caused by their inability to secure weather-resisting paint.

6. *Comments.* It is the opinion of the team making this survey that neither specific recommendations can be made nor conclusions drawn from the study of this single target. Attention is invited, however, to the following:

a. Ten days' production loss occurred because of atomic-bomb damage in the area, although only negligible physical damage was inflicted on the plant.

b. In the determination of vulnerability of buildings from aerial photographs, it is necessary to have complete knowledge of construction practices in the country under study. It would seem advisable that such pertinent information be obtained for future use in an emergency.

PART 5. EVALUATION OF MILITARY TARGET ANALYSIS

1. Hiroshima was primarily an Army headquarters and port of embarkation. Few industries of

strategic importance or major airfields were located within the immediate area. Few photographic reconnaissance missions were flown over the city, and little photographic interpretation was done.

2. *Airfields.* Hiroshima airfield was located on reclaimed land at the southern end of Yoshijima. It was developed as a subsidiary base for small land and float planes used in connection with the army headquarters. The surface of the field and runways was hard-packed gravel; the service apron and float plane ramps were concrete surfaced. Buildings were of frame construction of a relatively vulnerable type, and barracks, utility buildings and shops were of standard Japanese light, wood construction.

a. CINCPAC-CINCPOA Bulletin No. 8–45, of 15 January 1945, based on ground and prisoner-of-war intelligence and limited photo coverage, reported the field as "probably a secondary military airfield with adequate facilities, reported to have one asphalt-surface runway."

b. Interpron Two Photographic Interpretation Report No. 576 of 10 May 1945, based on complete photo coverage of this airfield area, reported the field substantially as it was found by the ground survey.

3. *Antiaircraft Defenses.* At the time when the survey team arrived in the field, the Japanese had nearly completed the removal of weapons in accordance with instructions from Supreme Allied Headquarters. Consequently, no accurate check could be made for comparative study. From spot checks of reported gun positions it appeared that the number of medium antiaircraft defenses had been overestimated, but that, in general, the locations of batteries were nearly correct. In some instances, abandoned locations were reported as gun positions. The Assistant Chief of Staff, G–2, of the Forty-first Division had made a complete check of all defenses in the Hiroshima area, but results were not available at the completion of the USSBS field survey.

4. *Army Headquarters and Army Provisioning.* Hiroshima was the administrative headquarters of the Chugoku Military District, and a primary embarkation point for the Japanese Army. The city had progressively become more important as a center of army activity beginning with the Sino-Japanese War, and as early as 1929 at least 28 percent of usable land area within the limits of Greater Hiroshima City had been taken over by the military for administration, training, housing, arming, and provisioning of troops. Activity continued to increase during World War II with the embarkation of troops for duty in the Central and South Pacific and later for the frenzied defense of the Marianas, Bonins and Ryukus. CINCPAC-CINCPOA Bulletin 8–45, reported the facts that the city was a primary port of embarkation for the Japanese Army and that extensive barracks and depot facilities were present.

5. *Harbor and Shipbuilding.* Hiroshima harbor facilities were used mostly for embarkation operations, supplying troops, fishing and inter-island transportation. No extensive dockage for large tonnage shipping could be easily provided because of the delta formation on which the city had been built. The military pier and municipal pier, both in Ujina, were suitable for extensive lighterage and small interisland boats, but not for the larger seagoing cargo and transport ships. Small shipyards at Ujina were equipped to construct the smaller craft. The Mitsubishi Shipbuilding Co. at the southerly end of Ebajima was equipped to fabricate and assemble larger ships, with three ways for accommodating ships of at least 3,000 tons. (One of these 3,000-ton ships was alongside the fitting-out pier at the time the field survey was made.) CINCPAC-CINCPOA Bulletin No. 8–45 in general correctly reported the facilities except for the Mitsubishi Shipbuilding Co. Maps of the area prepared later included corrected data based on complete photographic coverage.

6. *Industry.* Hiroshima had never been a highly industralized city; there were only three factories employing over 500 persons at the close of the war. No comprehensive preattack intelligence study of the area was found when preparing this phase of the target evaluation, but composite sources including Army Map Service, Joint Target Group, CINCPAC-CINCPOA and Interpron Two indicate that the principal industries were identified and the relative importance of industrial targets reported with reasonable accuracy.

PART 6. VALUE OF PHOTOGRAPHIC INTELLIGENCE TO GROUND SURVEYS

1. It is generally recognized that ground photographs are necessary to illustrate and verify data compiled by a unit conducting an on-the-ground survey of an area, and photographers are usually assigned to such a survey to satisfy this need. However, the potential usefulness of aerial recon-

naissance photography which has been taken prior to the arrival of the field survey is not always recognized. The following suggestions, based on the experiences of the photographic interpreters of Physical Damage Team 1, are offered as a guide in planning future surveys, so that this source of information may be more thoroughly utilized.

2. *Uses of Photographic Intelligence by Physical Damage Team 1.* *a.* In Hiroshima there was frequent difficulty in establishing the cause of damage since a typhoon and floods had ravaged the city a few weeks following the atomic-bomb attack but before the survey team had arrived on the scene. Photographs taken in the interval between the dates of the attack and the typhoon were often used to establish the cause of damage when reliable ground information was lacking.

b. When, as often happened, interrogation brought out conflicting statements, photographs were used to help establish the validity of one or the other of the statements.

c. Photographs were used to determine routes of travel and for orientation in the field.

d. Firebreaks in existence before the attack were plotted, and isolated areas of damage were located from aerial photographs.

3. *Use of Photographs in Facilitating Area Damage Assessment.* It is often impossible or inadvisable for a ground survey to complete a detailed study of the entire damaged area. In such instances a comprehensive damage analysis done from good quality photographs by a competent interpreter will accurately indicate the extent and relative degree of damage. In order to establish the degree of damage in more detail, spot checks can be made throughout the area.

4. *Recommendations for Use of Photographic Intelligence.* *a.* Preliminary to going into the field, the photographic interpreter accompanying the survey should be made familiar with its objectives and the expected procedures to be used in making the studies, so that he may provide the unit with all the necessary photographic aids and acquaint members of the unit with their use.

b. The nature of the survey will dictate what particular items the interpreter should furnish, but the following minimum list should be applicable in almost any case.

(1) An adequate supply of large-scale mosaics of the area from the latest and best available cover. These mosaics can be used for office worksheets, indexing maps, and briefing charts.

(2) An adequate supply of smaller-scale mosaics from the latest cover. These should be of such a size that they can be carried into the field as individual orientation guides, maps, or worksheets.

(3) If a grid system has been established before going into the field, this grid should be laid on a controlled mosaic, and other mosaics and photographs referenced to it.

(4) At least two sets each of the best quality pre-attack, the earliest post-attack, and all good quality post-attack cover.

(5) All pertinent photographic intelligence documents on the area concerned.

(6) All necessary personal interpretation equipment.

UNITED STATES STRATEGIC BOMBING SURVEY

LIST OF REPORTS

The following is a bibliography of reports resulting from the Survey's studies of the European and Pacific wars. Those reports marked with an asterisk (*) may be purchased from the Superintendent of Documents at the Government Printing Office, Washington, D. C.

European War

OFFICE OF THE CHAIRMAN

*1 The United States Strategic Bombing Survey: Summary Report (European War)
*2 The United States Strategic Bombing Survey: Over-all Report (European War)
*3 The Effects of Strategic Bombing on the German War Economy

AIRCRAFT DIVISION

(By Division and Branch)

*4 Aircraft Division Industry Report
5 Inspection Visits to Various Targets (Special Report)

Airframes Branch

6 Junkers Aircraft and Aero Engine Works, Dessau, Germany
7 Erla Maschinenwerke G m b H, Heiterblick, Germany
8 A T G Maschinenbau, G m b H, Leipzig (Mockau), Germany
9 Gothaer Waggonfabrik, A G, Gotha, Germany
10 Focke Wulf Aircraft Plant, Bremen, Germany
11 Messerschmitt A G, Augsburg, Germany { Over-all Report; Part A; Part B; Appendices I, II, III
12 Dornier Works, Friedrichshafen & Munich, Germany
13 Gerhard Fieseler Werke G m b H, Kassel, Germany
14 Wiener Neustaedter Flugzeugwerke, Wiener Neustadt, Austria

Aero Engines Branch

15 Bussing NAG Flugmotorenwerke G m b H, Brunswick, Germany
16 Mittel-Deutsche Motorenwerke G m b H, Taucha, Germany
17 Bavarian Motor Works Inc, Eisenach & Durrerhof, Germany
18 Bayerische Motorenwerke A G (BMW) Munich, Germany
19 Henschel Flugmotorenwerke, Kassel, Germany

Light Metal Branch

20 Light Metals Industry of Germany { Part I, Aluminum; Part II, Magnesium
21 Vereinigte Deutsche Metallwerke, Hildesheim, Germany
22 Metallgussgesellschaft G m b H, Leipzig, Germany
23 Aluminiumwerk G m b H, Plant No. 2, Bitterfeld, Germany
24 Gebrueder Giulini G m b H, Ludwigshafen, Germany
25 Luftschiffbau Zeppelin G m b H, Friedrichshafen on Bodensee, Germany
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